N A S A C O N T R A C T O R
R E P O R T

Prediction and Verification of Creep Behavior in Metallic Materials and Components for the Space Shuttle Thermal Protection System

VOLUME III

Phase III — Full Size Heat Shield Data Correlation and Design Criteria

AUGUST 1975

Prepared By **B. A. Cramer** *and* **J. W. Davis**

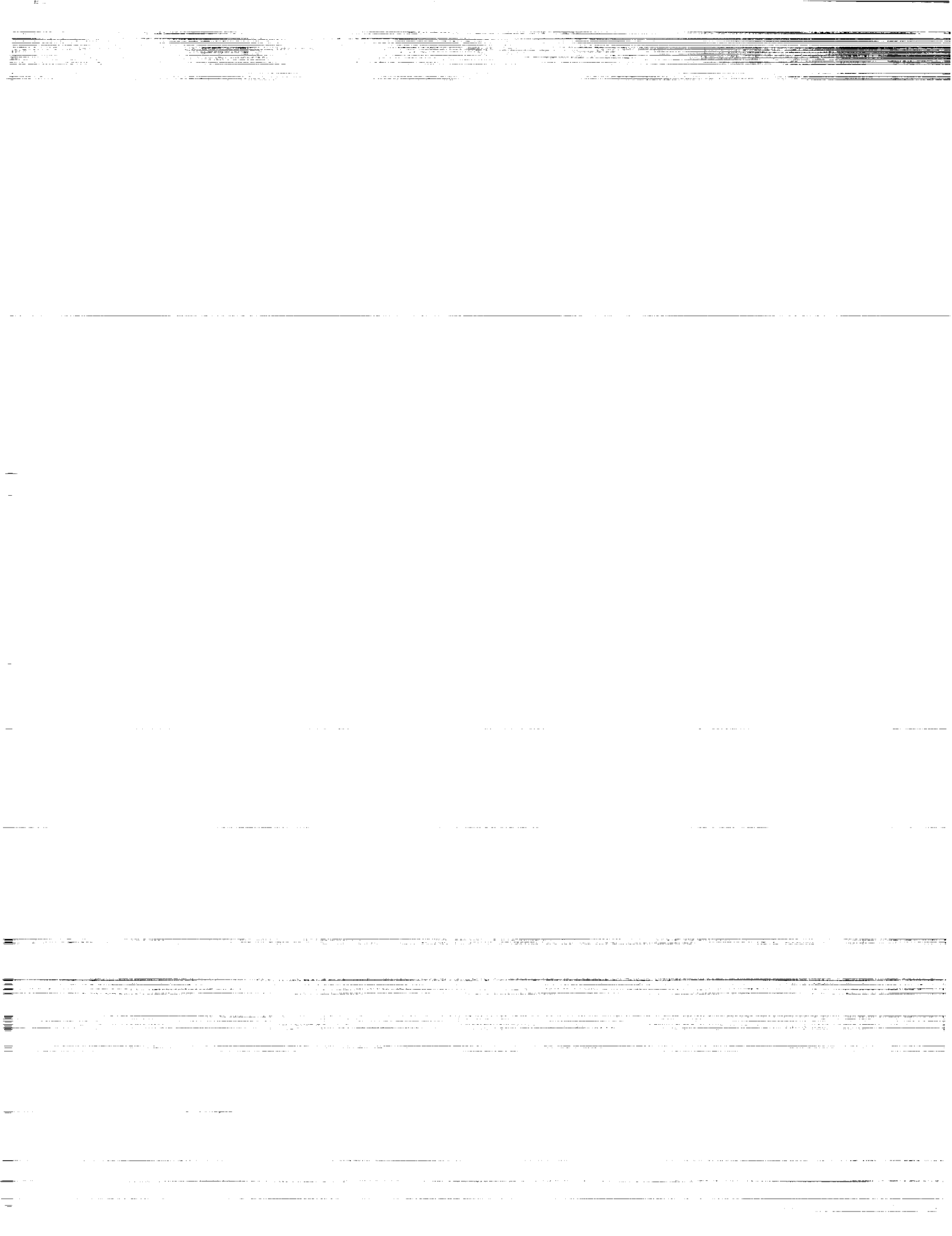**MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST**

MCDONNELL DOUGLAS

CORPORATION

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION ● WASHINGTON, D.C. ● AUG 1975

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ABSTRACT

Analysis methods, developed in Phase II, for predicting cyclic creep deflection
in stiffened panel structures, were applied to full size panels. Results were
compared with measured deflections from cyclic tests of thin gage L605, Rene' 41,
and TDNiCr full size corrugation stiffened panels for which data were available in
the literature. Empirical equations used in the analysis were developed for each
material based on correlation with tensile cyclic creep data during Phase I of the
program.

Based on results from the study, a design criteria is formulated for metallic
TPS panels subjected to creep. This criteria addresses TPS design considerations,
data requirements for creep analysis, and creep deflection analysis. Also included
in this report are the users' information and listing for the TPSC (Thermal Pro-
tection System Creep) Computer Program developed to calculate creep deflections.

FORWARD

This report was prepared by McDonnell Douglas Astronautics Company - East under Contract NAS 1-11774 for the National Aeronautics and Space Administration, Langley Research Center, Hampton, Virginia. It was administered under the direction of the Materials Division, Materials Research Branch, with Mr. D. R. Rummler acting as the technical representative of the contracting office. The McDonnell Douglas program manager was Mr. J. W. Davis. Mr. B. A. Cramer was responsible for structural considerations, analytical methods, and data analysis.

The TPSC Computer Program analysis approach was initiated in the MDAC-E Advanced Structural Technology Group by Mr. O. R. Otto and Mr. J. K. Lehman. Mr. B. A. Cramer was responsible for development of the TPSC program under the contract. Mr. M. B. Gedera assisted in programming the TPSC program.

This report covers the period from December 1974 to April 1975.

i. SUMMARY

Presented in this report are the results of both the Phase III and Phase IV contract phases. Phase III was directed at correlating results of full size panel cyclic testing based on material cyclic creep response behavior determined in Phase I studies (Reference 1) and analysis capability developed in Phase II (Reference 2). Full size panel data for this effort, were obtained from the literature. Phase IV effort was directed at summarizing program results into a TPS panel design criteria. Phase III is presented in Sections 2 through 4 of the report and Phase IV is presented in Section 5. The Users information and listing for the TPSC (Thermal Protection system Creep) Computer Program developed during Phase II are presented in Appendices B and C respectively.

Comparisons of predicted and test deflections are presented for L605 panels and Rene' 41 panels tested at McDonnell Douglas Corporation and for Haynes 25 (L605) and TDNiCr panels tested at Grumman Aerospace Corporation.

Resulting predictions for the L605 and Rene' 41 panels provided good correlation with test results. For both materials there was approximately a factor of two difference between test deflection results for two identical panels tested simultaneously. No explanation for this difference could be determined, Predictions for these panels were made both at the center, where temperatures were highest and at the panel transverse edges where temperatures were somewhat lower. For the L605 panels the predicted center deflections were approximately 20% less than the lowest panel test deflection agreed closely with the average test deflections. For the Rene' 41 panels the predicted deflection was very close to the higher of the test deflections at the panel center. Sensitivity of predicted deflections to variations in material gage and test temperature was demonstrated for the Rene' 41.

Predictions for the Haynes 25 panel and TDNiCr panel were both low in comparison to test deflections although considerable variation was evident in the data measured for four spans on the TDNiCr panel and the prediction was within the data range. This variation in test data could not be accounted for by temperature variations in the panels. The trend in the prediction relative to test deflections as a function of cycle for TDNiCr was shown to be consistent with prediction capability of the empirical cyclic creep equation. Test deflections for the Haynes 25 panel were two times higher than predictions.

TABLE OF CONTENTS

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

TABLE OF CONTENTS (Continued)

LIST OF FIGURES

LIST OF FIGURES (Continued)

LIST OF FIGURES (Continued)

LIST OF TABLES

1.0 INTRODUCTION

One of the design requirements of reentry vehicle metallic thermal protection systems (TPS) is that deflections, occurring during ascent and entry mission phases, due to differential pressure and thermal loading, do not exceed design limits. These deflection limitations are established to maintain the aerodynamic shape, minimize localized aerodynamic heating and to minimize the need for panel refurbishment. Because deflections include permanent deformation due to creep, methods for predicting these deformations are needed.

Several arrangements of metallic TPS components have been investigated in the coures of previous spacecraft studies. The baseline design used in the McDonnell Douglas Phase B Shuttle Study Program is shown in Figure 1-1. Radiative metallic panels form the outer moldline. These panels are backed by fibrous insulation blankets. Differential air pressure loads on the panels are transmitted by beam bending to transverse support beams located at approximately a 50 cm ($\sim$20 inches) spacing. Retaining straps are attached to the transverse support beams and retaining straps. Longitudinal joints between panels provide normal-to-panel shear continuity between adjacent panels, preventing joint gapping by forcing adjacent panels to deflect simultaneously under applied loads. Transverse support beams transmit loads to support struts which carry the loads to primary load carrying structure. Drag links, spanning diagonally between transverse support beams and primary structure, provide support structure system stability and carry longitudinal loads.

During Phase I (Reference 1) of this program, the influence of cyclic entry conditions on creep response was investigated for four material alloys: Ti-6Al-4V, Rene' 41, L605, and TDNiCr. Analysis of tensile creep test data during this phase resulted in empirical equations, for each material, which describe cyclic creep

1-1

PRIMARY STRUCTURE —

INBOARD

SUPPORT
STRUT

INSULATION
BLANKET

DRAG LINK
SUPPORT
GUSSET

DRAG LINKS

RETAINING STRAP

METALLIC THERMAL PROTECTION
SYSTEM PANEL

TRANSVERSE SUPPORT BEAM

TRANSVERSE JOINT
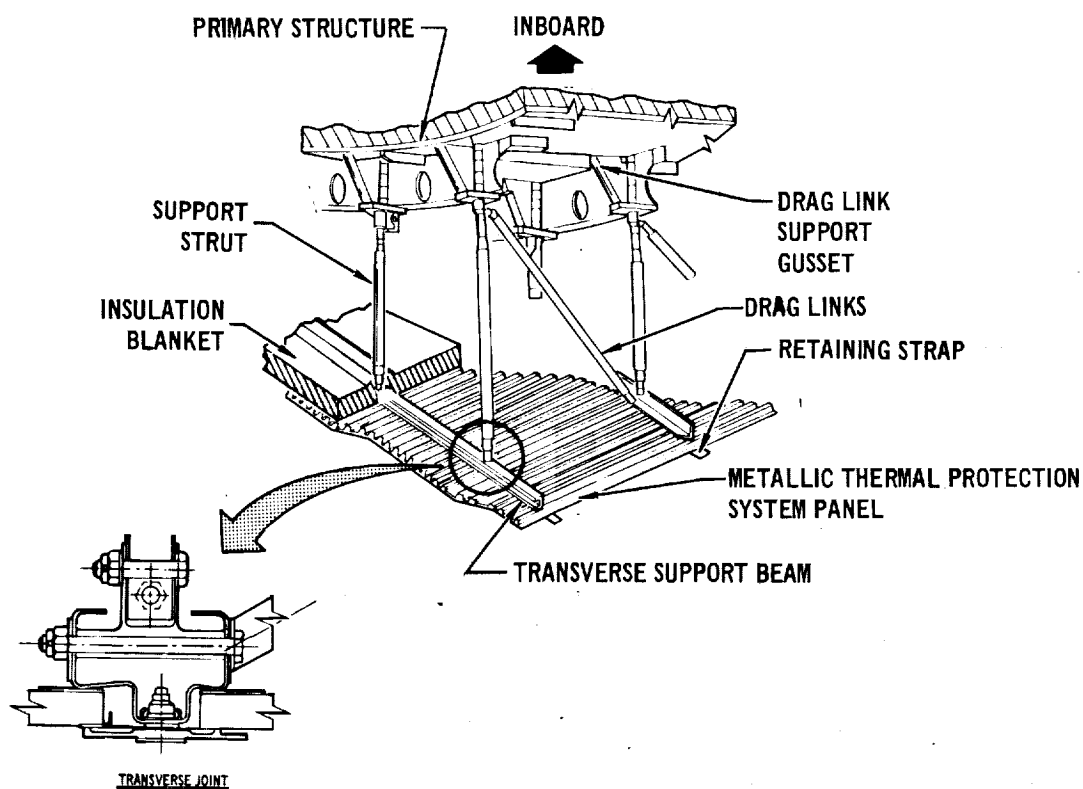
FIGURE 1-1 TYPICAL METALLIC THERMAL PROTECTION SYSTEM STRUCTURE

response characteristics as a function of stress, temperature, and time. These
equations were used in conjunction with the time and strain hardening theories of
creep accumulation to investigate creep prediction capability for cyclic trajectory
stress and temperature profiles.

Phase II (Reference 2) was directed toward developing and verifying capability
for prediction of creep deflection in metallic heat shields subjected to cyclic
entry environments.

A computer program, Thermal Protection System Creep (TPSC) was developed for
predicting beam creep deflections (Appendix B and C). This program offers an approach
to creep predictions through application of iterative techniques and numerical
integration. In the analysis, panel length is divided into segments over which
bending moments are assumed constant and panel depth is divided into increments
over which stresses and strains are assumed constant. Using a linear strain
assumption, beam rotations are iteratively determined, based on either the time
hardening or strain hardening theories of creep accumulation. Material cyclic
creep response properties were defined by empirical equations developed from tests
of tensile creep specimens in Phase I. The TPSC program capability includes
definition of temperature as a function of beam length and depth, application of
either the strain hardening or time hardening theory of creep accumulation, and
the application of bending distributions for a full size panel based on the edge
stiffness and the longitudinal and transverse panel stiffness. Program output
includes defintion of both elastic and creep deflected shapes, residual stresses,
and creep strains as a function of cycle.

Seventeen subsize panel specimens, 6.35 cm by 3.05 cm, were tested to provide
creep deflection data for verification of prediction capability. Corrugation cross
section specimens were fabricated for test using thin gage ($\sim$.025 cm) L605, Rene' 41,
Ti-6Al-4V, and TDNiCr sheet material. Rib cross section specimens were also

1-3

fabricated for test using thicker gage (∿.060 cm) L605 and Ti-6Al-4V sheet material.
These materials were procured for use both in Phase I and II. Each test consisted
of cycling the panel for up to 100 entry thermal and bending load profiles represen-
tative of Shuttle entry missions. Testing was conducted in a vacuum furnace, using
a load mechanism specifically designed to apply a two-point panel load that would
be independent of panel deflection. Permanent deflections, due to creep, were
measured as a function of cycle.

Comparisons of subsize panel creep deflection predictions with test results
were made. Generally, good correlation was obtained between predicted and test
deflections.

The objective of the program Phase III effort was to analyze full size panel
creep data obtained from available test programs and to compare test results with
prediction using methods of analyses developed during Phase I and II. Every effort
was made to include all possible variations that could be ascertained from the
documentation that might affect creep response so that as much confidence as
possible could be associated with the comparison of predicted and test results.
To this extent, the documented test data and results are summarized in this report.
In addition, loads, temperatures, and panel geometry data required for creep
analysis are reported.

The international system of units (SI) are used in this report. U.S. Customary
Units are also generally provided. Applicable conversion factors are presented in
Appendix A.

2.0 Background from Phase I and II

During Phase I and II of this program, the influence of cyclic entry conditions on creep response of L605, Rene' 41, TDNiCr, and Ti-6Al-4V were investigated and prediction capability for TPS panel creep deflections was developed. These cyclic creep data and analysis methods have been applied in the evaluation of full size panel test data in Phase III. Presented in this section are discussions of Phase I and Phase II results as they apply to the Phase III evaluation of full size L605, Rene' 41, and TDNiCr TPS panel test data.

2.1 PHASE I - CYCLIC TENSILE TESTING

In Phase I, thin gage tensile specimens were tested under cyclic loads and temperatures. Initially, creep response data were generated in what was designated as series of basic cyclic tests. These tests were conducted using the stress and temperature profiles shown in Figure 2-1 where the time per cycle was twenty minutes and the time between cycles (required for heat up and cool down portions of the profile) was 35 minutes. For each material, tests were conducted at three stress levels at each of four temperatures covering the range of temperature applicability for the respsective materials.

Test temperature ranges were 978K (1300°F) to 1255 (1800°F) for L605, 1033K (1400°F) to 1155K (1620°F) for Rene' 41, and 1089K (1500°F) to 1478K (2200°F) for TDNiCr. Stress levels were selected at each temperature to yield 100 cycle creep strains of up to approximately 1%, the range of interest in analysis of TPS panels.

Analysis of cyclic tensile test data for each material resulted in empirical equations describing cyclic creep response characteristics as a function of stress, temperature, and time. These equations are presented in Table 2-1. Each equation represents a fit of cyclic data based on regression analysis. For each material

2-1

STRESS – TEMPERATURE

TEMPERATURE

STRESS

TIME/CYCLE

TIME
BETWEEN
CYCLES
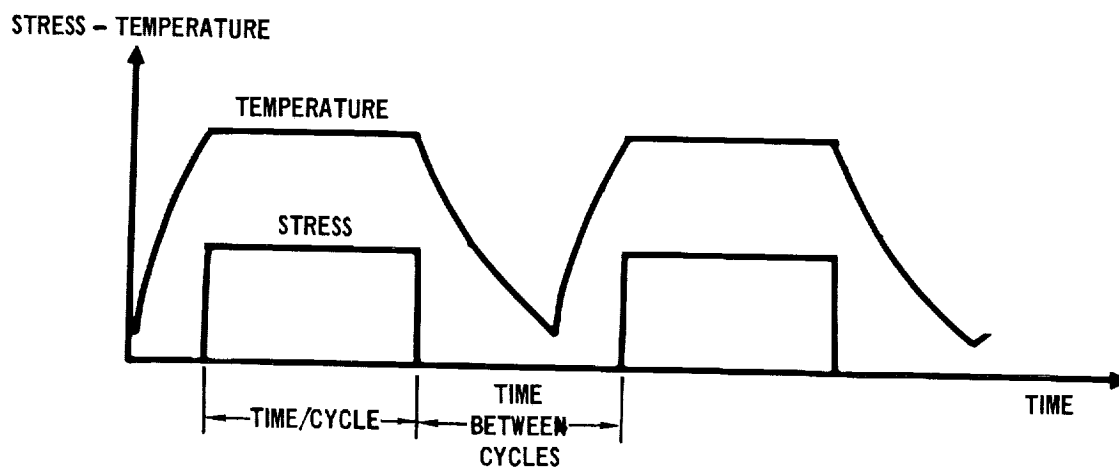
TIME

FIGURE 2-1 STRESS AND TEMPERATURE PROFILES FOR PHASE I TENSILE CYCLIC CREEP TESTS

TABLE 2-1 CYCLIC CREEP EQUATIONS DEVELOPED FOR PHASE I TENSILE CREEP DATA

t = time, hours
σ = stress, MPa
T = Temperature, K/1000

MATERIAL	EQUATION	APPLICABLE TEMPERATURE MAXIMUM
L605	$\ln \varepsilon = -2.89413 - .01743t + .54892 \ln t + 1.31015 \ln\sigma -6.66548 (1/T) + .19131\, \sigma \ln T + .00021 (T\sigma t).$	1255 K (1800°F)
RENE'41	$\ln\varepsilon = -39.55860 + 29.13646T + .71922 \ln t + .92125 (\ln\sigma - 1.931) -.0000016\sigma^2 + .08183 (\ln\sigma - 1.931)^3 - .000125\, t\sigma T + .0000105t^3$	1155 K (1620°F)
TDNiCr	$\ln \varepsilon = -3.48443 -10.37282 (\frac{1}{T}) + .28314 \ln t +2.00118 \ln\sigma$	1478 K (2200°F)

NOTE: The equation developed for Ti-6Al-4V can be found in References 1 and 2.

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considerable effort was directed toward determining appropriate equation forms, including stress, time and temperature interaction terms, to provide a "best fit" over the entire range of data resulting in the different equation forms shown. Typical comparisons of the tensile cyclic data and empirical equation predictions for each material are shown in Figures 2-2 through 2-4. Generally, the TDNiCr specimens failed at creep strains below .15%.

Because the empirical equations presented in Table 2-1 were derived from 100 cycle testing for 20 minutes at load per cycle, the total time of applicability of each of the equations is 33.3 hours. In the analysis of TPS panels subjected to mission load and temperature profiles, the profiles are "idealized" by dividing them into steps of constant load and temperature. To investigate the applicability of the empirical equations to these profiles, tests were also conducted for each material using the profile shown in Figure 2-1 with a ten-minute per cycle time at load and peak temperature. Results of these comparisons for each of the 10 minutes per cycle and 20 minutes per cycle materials are shown in Figure 2-5 for equal total time at load. Because close agreement between these test data was obtained, the equations are considered to be applicable in analysis of idealized mission profiles where smaller time steps are used. Also, this total time of equation applicability of 33.3 hours will be important in the analysis of test data where longer times of the stress and temperature profiles may result in a reduction of the number of cycles over which the equations are applicable.

Cyclic tensile tests were also conducted where stress was varied as a function of cycle (stepped stress tests) and where stress and temperature were varied within each cycle (mission profile tests). These test data were used to evaluate the applicability of the time and strain hardening theories of creep accumulation. Comparison of predicted creep strains using these hardening theories in conjunction with the empirical equations indicated that neither theory consistently provided

2-4
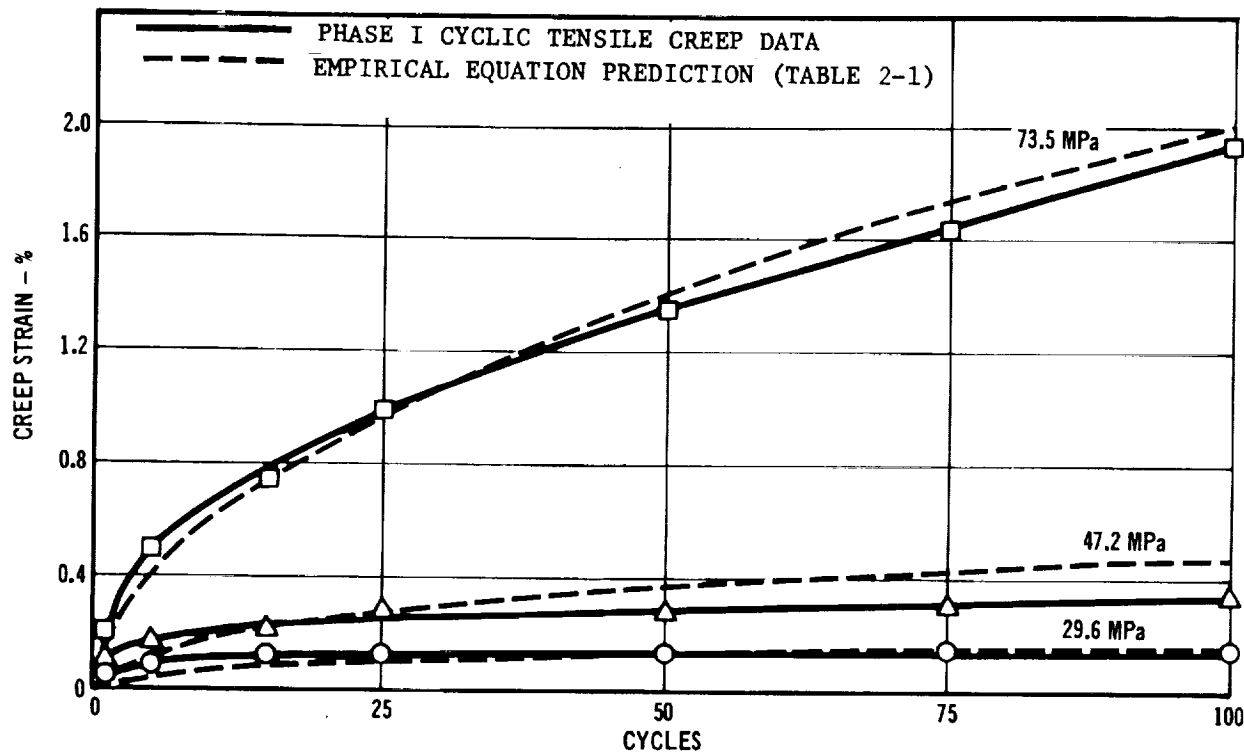
FIGURE 2–2 COMPARISON OF L605 PREDICTED AND CYCLIC TEST CREEP STRAINS AT 1144 K
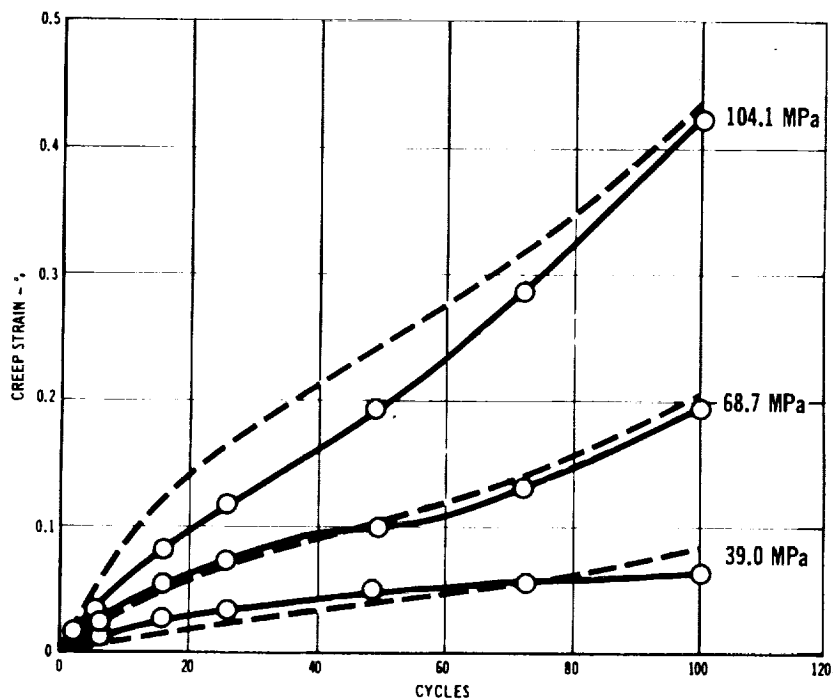
FIGURE 2–3 COMPARISON OF RENE 41 PREDICTED AND CYCLIC TEST CREEP STRAINS AT 1111 K

2–5
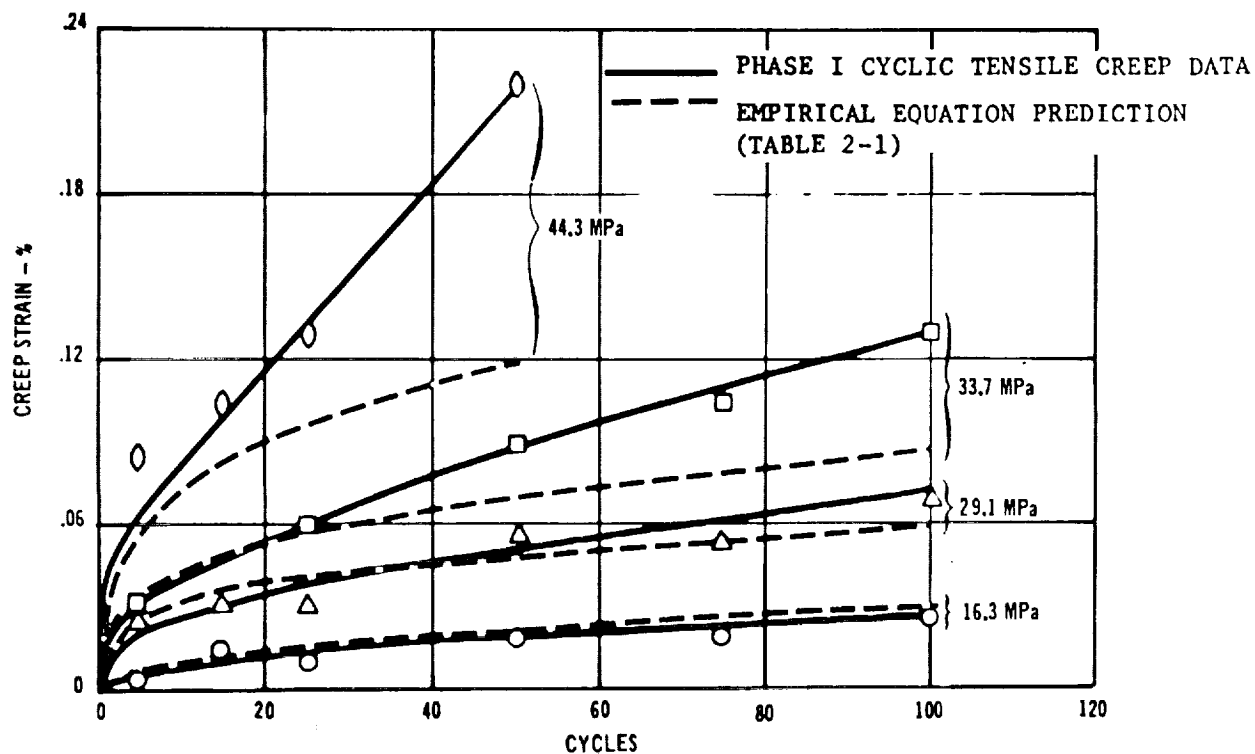
FIGURE 2-4 COMPARISON OF TDNiCr PREDICTED AND CYCLIC TEST
CREEP STRAINS AT 1478 K
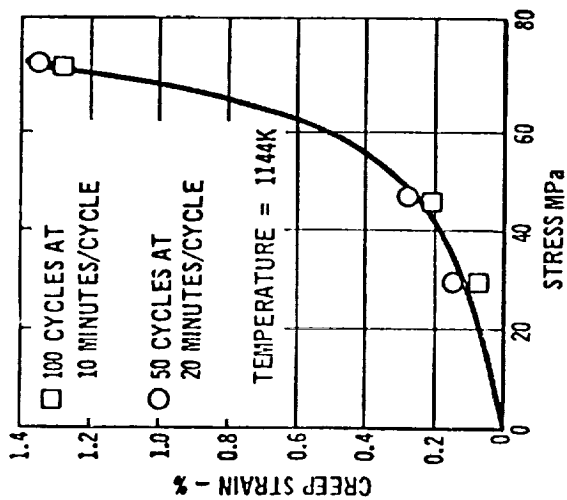
(b) RENE '41

(a) L605
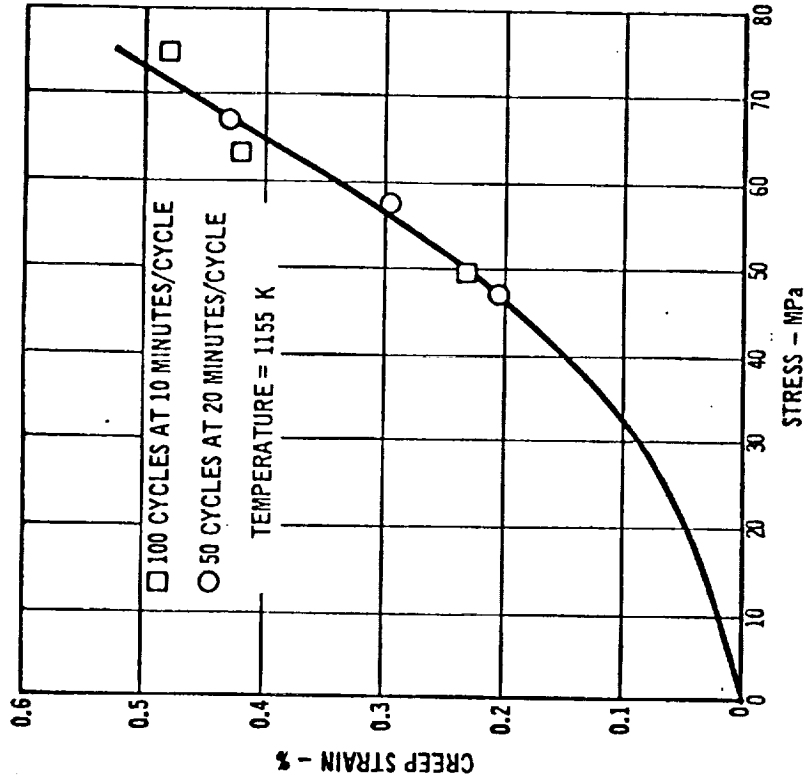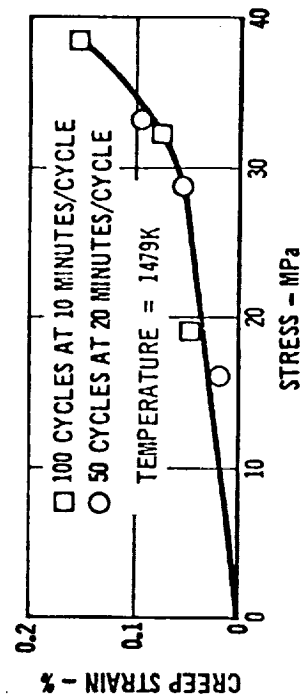
(C) TDNiCr

FIGURE 2-5 CYCLIC TENSILE CREEP STRAINS AT DIFFERENT TIME
PER CYCLE COMPARED AT EQUAL TIME AT LOAD

good predictions. Comparison of strain hardening and time hardening predictions with L605 cyclic tensile data showed that the strain hardening theory provided the best predictions for tests where stress was continually decreased as a function of cycle and the time hardening theory provided the best prediction for tests where stress was continually increased as a function of cycle. Therefore, an approach was proposed where both strain hardening and time hardening theories were used at each analysis step depending on whether the creep strain rate decreased or increased, respectively. Although this improved predictions for the L605 mission profile trajectory tests, it did not improve prediction for the other materials.

For Rene' 41, predictions based on the time hardening theory of creep accumulation were generally considered best. Predictions based on the strain hardening theory of creep accumulation were found to be approximately the same as for time hardening in predicting strains for testing where the stress was continuously increased as a function of cycle. Both predictions were close to test values. For specimens where stress was continually decreased, the time hardening predictions were up to 30% higher than test strains. However, predictions based on strain hardening were even higher, up to 75% higher than the time hardening predictions.

Predictions of creep strains for TDNiCr trajectory profile tensile tests using the cyclic creep equation, were found to be from 30% to 70% of test strains at 100 cycles. The applicability of hardening theories used in panel analysis will significantly effect prediction capability.

Another variable considered in Phase I tensile creep testing was the possible effect of recovery phenomena. To investigate this, tests were conducted where the stress profile was maintained for a longer period of time while temperature was being decreased rapidly, as shown in Figure 2-6(a). These comparative tests were conducted on L605 and Rene' 41 tensile specimens. Test results, shown in Figure 2-6(b), indicated that no variation in creep strains could be determined for the

2-8

(a) CYCLE PROFILES

(b) L605 AT 1144 K

(c) RENE '41 AT 1111 K
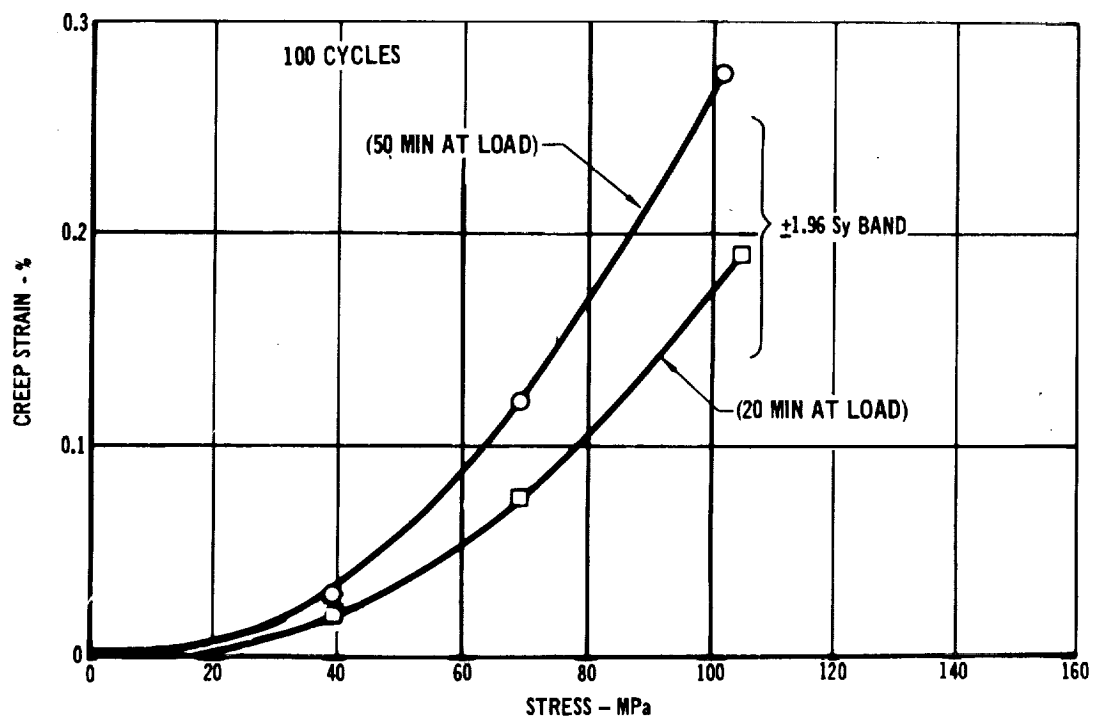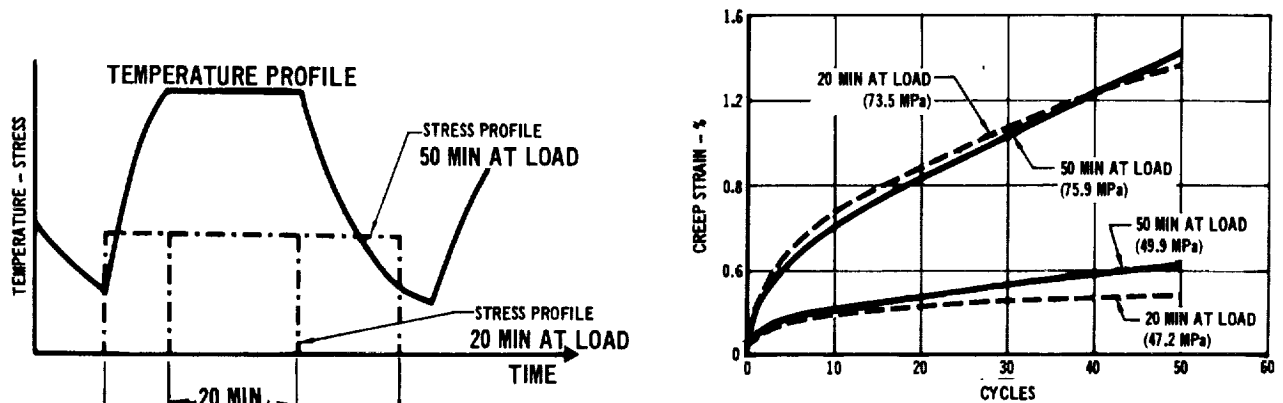
FIGURE 2–6 EFFECT OF MAINTAINING LOAD DURING HEAT UP AND
COOL DOWN PORTIONS OF THE CYCLE PROFILE

L605 specimens, as indicated by the strain-time data plots. However, Rene' 41 creep strain results were consistently higher for each of three specimens tested. These results, plotted as a function of the stress levels, at 100 cycles are shown in Figure 2-6(c). This variation in creep strains for Rene' 41 was greater than expected based on data scatter as determined in the development of empirical equations. From these results it is difficult to draw conclusions as to the differences between the mission profile test results and predictions based on empirical equations developed for the twenty minute per cycle stress level. However, it has been demonstrated that an effect, due to possibly a material recovery phenomena, may exist to different degrees in the different materials, which may effect panel deflection predictions.

The empirical cyclic creep strain equations developed in Phase I were based on tests conducted on the thin gage sheet specimens ($\sim$.025 cm) for each material. Initially in Phase I, steady state tests were conducted on both these thin gage materials and also on specimens from a sheet thickness of .064 cm. An effect of gage on creep response (thin gages creep faster) was noted in the L605 steady state tests and also in steady state data obtained from the literature. This effect is attributed to a change in material processing at about t = .064 cm. This type of effect is discussed here to point out possible effects from sheet to sheet and due to thickness which may effect prediction capability in applying empirical equations developed on this program to panel tests from other programs.

For each of the alloys, cyclic tensile creep tests were conducted in Phase I to obtain data for the assessment of possible effects of atmosphere pressure on creep response. To provide these data, replicate tests were conducted, using idealized mission stress and temperature profiles. However, atmospheric pressure was held constant at 1.33 Pa, in one of the tests while a mission pressure profile was

applied in the other test. In each case variations in creep strain results were relatively small and were considered within the range of scatter for replicate tests. Therefore, no effect was attributed to atmospheric pressure.

2.2 PHASE II - PREDICTION AND VERIFICATION OF PANEL CREEP DEFLECTIONS

Phase II was directed toward developing and verifying capability for prediction of creep deflections in metallic heat shields subjected to cyclic entry environments.

A computer program, Thermal Protection System Creep (TPSC) was developed for predicting beam creep deflections and was used to predict results of subsize panel testing. Details of this work have been reported in the Phase II Summary report (Reference 2) and in the TPSC Program User Manual (Appendix B). This program offers an approach to creep predictions through application of iterative techniques and numerical integration. In the analysis, panel length is divided into segments over which bending moments are assumed constant and panel depth is divided into increments over which stresses and strains are assumed constant. The single skin corrugation TPS configuration with a skin bead, is automatically idealized through appropriate geometry input to the program. All of the full size panels analyzed in Phase III were of this configuration.

Using a linear strain assumption, beam rotations are iteratively determined, based on either the time hardening or strain hardening theories of creep accumulation. Material cyclic creep response properties developed from tests of tensile creep specimens in Phase I were used in the analysis and because the time hardening approach provided more consistently the best predictions of subsize panel data in Phase II, it was used for analysis purposes in Phase III. The TPSC program capability also includes definition of temperature as a function of beam length and depth, and the application of bending distributions for a full size panel based on the edge stiffness and the longitudinal and transverse panel stiffness. The

capability of including temperature as a function of panel length was utilized in analysis of the Reference 3 studies (Section 3.1) where temperature distributions were known.

Moment distributions are internally defined based on uniform pressure loads and simple panel supports. In addition, the moment distribution can be automatically calculated as a function of panel edge stiffness and the ratio of panel stiffness in the longitudinal and transverse directions. This option is based on combining solutions for an isotropic plate with two sides simply supported and two sides elastically supported as offered by Timoshenko (Reference 4) and the solution for an orthotropic plate with four sides simply supported as offered by Lekhnitskii (Reference 5). This option provides a first order approach to account for Poisson's effects in orthotropic plate structures. However, this option was not applied to the analysis of full size panel data in Phase III because of the large ratio of longitudinal to transverse stiffness for corrugated panels analyzed and because of the general lack of edge stiffness in the test panels. Edge stiffness was generally minimized in the full size panel tests to simulate as closely as possible actual entry vehicle panel conditions.

Both pressure and temperature load inputs are based on idealization of the test profiles into discrete time steps. During Phase I, cyclic tensile tests were conducted for both mission profiles and idealized profiles. Comparison of test results indicated that a minimum number of steps (4 steps used in Phase I testing) provided good correlation of results.

The following basic assumptions are made in the analysis:

a) Only bending stresses are considered in the analysis. Deflections due to shear are assumed negligible.

2-12

b) Total creep strain plus elastic strain distributions through the panel
    depth are linear.

c) Load and temperature distributions and calculated deflections are assumed
    symmetrical with respect to the panel centerline

d) Creep response equations, defined by the user, are assumed to be applic-
    able for both tensile and compressive stresses. In addition, the equations
    developed based on Phase I cyclic testing are assumed to be applicable for
    the sheet material used in fabrication of the full size panels.

e) Stress distributions are assumed uniform in the horizontal thin gage
    sections of the panel cross sections. In particular, the thin gage skin,
    loaded in compression, is assumed to carry load uniformly (except as
    altered by the My/I distribution in the bead) across the pitch length.

It is difficult to determine how much each of these assumptions might influence
the predictive capability of the TPSC program. The first three of these assumptions
probably are the most applicable to the analysis. The last two assumptions are of
most concern as to applicability. Certainly the scatter documented in literature
for sheet to sheet variations in creep response as well as variations in TPS panel
skin stress distributions evidenced through strain gage data (References 3 and 6)
and the occurrence of skin buckling (References 2 and 3) noted in TPS panel test-
ing will effect creep deflections. Applicability of the hardening theories to the
real material response will also be an unknown in the full size panel analysis.

Even with all of these assumptions considered, the TPSC computer program has
been demonstrated to provide needed capability for prediction of permanent
deflections, due to creep, in entry vehicle metallic thermal protection system
panels subjected to complex cyclic loading conditions. The TPSC program is written
in Fortran IV and is operational on the CDC 6600.

2-13

Four L605, three Rene' 41, four Ti-6Al-4V, and two TDNiCr subsize (6.35 cm by 30.5 cm) corrugation stiffened TPS panels were tested to provide creep deflection data for verification of prediction capability in Phase II. These specimens were fabricated using thin gage (approximately .025 cm) sheet material, however, the section geometry was more compact (pitch = 1.91 cm and depth = 1.27 cm) than those found in the full size panel testing. In addition, no skin bead was used in the subsize panels. Rib cross section specimens were also fabricated for test using thicker gage (∿.064 cm) L605 and Ti-6Al-4V sheet material.

Testing of subsize panels was conducted in a vacuum furnace, using a load mechanism specifically designed to apply panel bending loads that would be independent of panel deflection. Permanent deflections, due to creep, were measured as a function of cycle. Each test consisted of cycling the panel for up to 100 temperature and bending load profiles representative of Shuttle entry missions. Two types of cyclic profiles were used. The first consisted of a constant load and temperature applied for twenty minutes, with heat up and cool down periods at zero load yielding total cycle time of fifty five minutes. Two L605, two Rene' 41, three Ti-6Al-4V, and one TDNiCr subsize panels were tested to this type profile. The second type of profile consisted of mission temperature and load profiles for the same total cycle time as for the constant load cycles. The remainder of the seventeen panels (four L605, one Rene' 41, three Ti-6Al-4V, and one TDNiCr) were tested to these mission profiles.

Comparisons of the subsize panel creep deflection predictions with test results were made in Phase II (Reference 2). Predicted deflections, as a function of cycle, for the L605 subsize panels tended to be lower than test values for approximately 15 cycles and then increase to higher than test values by the con- clusion of the test. This same trend was noted in the comparison of tensile

creep data and empirical equation predictions. Predicted panel creep deflections obtained using the time hardening theory of creep accumulation were found to generally yield the best predictions. Predicted deflections for the Rene' 41 panels generally were not as close to test values as had been demonstrated in the case of L605. Again, the time hardening theory of creep accumulation provided the best deflection predictions, although these predictions were lower than test data for the mission profile and higher than test data for the constant load and temperature profiles. Predictions for the Ti-6A1-4V panels generally agreed with test results. The shape of the predicted deflection curve as a function of time (or cycle) was in good agreement with the test data which is consistent with the prediction capability of the empirical equation for Ti-6A1-4V. Predictions for the TDNiCr subsize panels were a factor of two high in one test and a factor of two low in the other test. No rational was determined for this apparent inconsistency although all deflections were small ($\sim$.05 cm).

3.0 ANALYSIS OF FULL SIZE PANEL DATA

The Phase III effort consists of evaluation and analysis of full size panel data. In each case, analysis consists of the idealization of test load and temperature profiles and calculation of the TPS panel deflections using the material cyclic creep properties developed in Phase I and creep deflection prediction methods developed in Phase II.

Four sets of panel data were evaluated in this phase. These data were for L605 panels and Rene' 41 panels tested at McDonnell Douglas Corporation (Reference 3) and Haynes 25 (L605) and TDNiCr panels tested at Grumman Aerospace Corporation (References 6, 7 and 8). Although it was desirable to evaluate data on panels for each of the four materials studied in Phases I and II, no test data on testing of full size titanium TPS panels were found.

3.1 SSTP PROGRAM L605 AND RENE' 41 PANELS

The SSTP program (Supplementary Structural Test Program) was a supplement to the Space Shuttle System Program Definition, conducted at McDonnell Douglas Astronautics Company - East. This program consisted of designing, fabricating, and testing of Space Shuttle primary structure and thermal protection systems. Purposes of the program were to verify feasibility of design concept, provide design data, demonstrate producibility, demonstrate reusability and verify unit weight predictions. Included in this program was the testing of L605 and Rene' 41 full scale metallic TPS panels.

Each test assembly consisted of two test panels, smaller side panels to provide proper boundary conditions, support beams and struts, and a section of simulated tank structure. Figure 3-1 shows the test assembly. The two primary test panels are each 50.8 cm. x 50.8 cm (20" x 20"). The 12.7 cm (5 in.) wide

3-1

(a) FULL SCALE
SSTP PANELS
IN TEST FIXTURE

TEST PANELS

50.8

79.5

51.5

SIDE PANELS

127.

PLAN VIEW
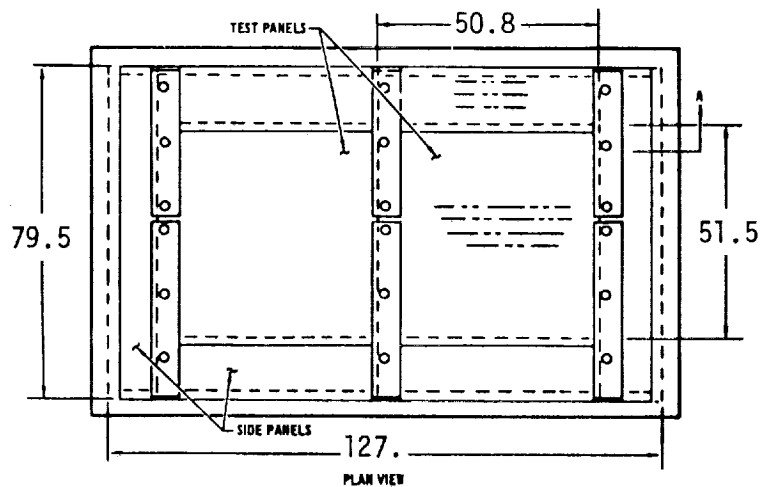
(b) SSTP
SUPPORT STRUCTURE
AND INSULATION
LARGE PANEL
TEST

SIMULATED TANK RING   PURGE LINER   TANK WALL

45.7

DRAG LINK   SUPPORT STRUT

FIXTURE
MOUNTING GLANGE   PANEL   SECTION VIEW   INSULATION
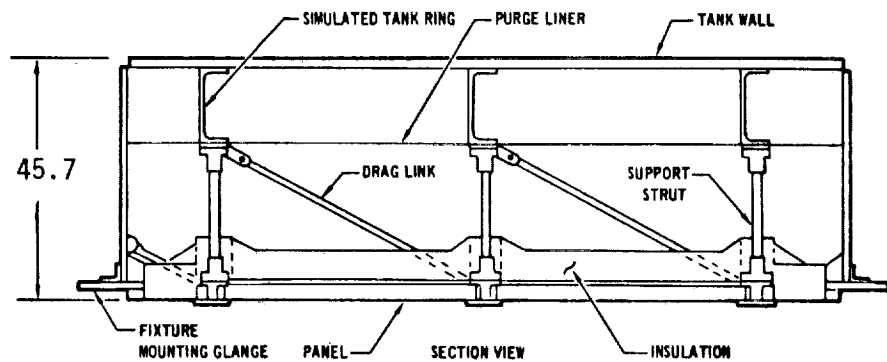
(c) SSTP
LARGE PANEL
DETAILS

TRANSVERSE JOINT

LONGITUDINAL JOINT

(d) PANEL
DESIGN DETAIL

.28 BEAD

3.63

1.65   .965
.018 CORRUGATION
.025 FACE SHEET

RENE'41

.28 BEAD

3.63

1.85

2.12
.018 CORRUGATION
.025 FACE SHEET

L605
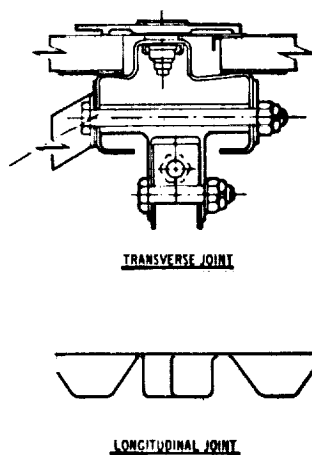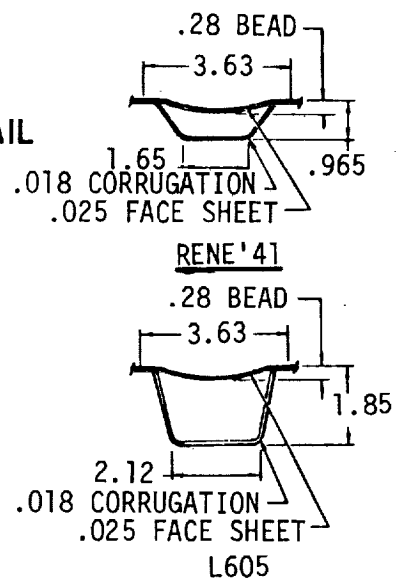
FIGURE 3-1 SSTP PANEL TEST GEOMETRY

side panels simulated the boundary conditions by isolating the primary

panels from the water cooled test fixture. The support beams for the panels were

50.8 cm (20 in.) apart. The panels were supported by "hat section beams and

retaining straps with sufficient clearance to permit free expansion. The beams in

turn were supported by tubular struts and drag links. Figures 3-1(a), 3-1(b), and

3-1(c) show the details of this construction. The beam also supported the insula-

tion packages. To accommodate thermal expansion, the panels were mounted with

slip fit joints. For the analysis, the panels were assumed to have simple supports

at the edges because end fixity and friction were difficult to define.

The panels of both materials were the same basic design; single faced,

corrugation stiffened, with beaded face skins and reinforcing doublers on the ends

of the corrugations. The doublers served a dual purpose. They not only stiffened

the corrugation ends, but they were also made thick enough so that after assembly

a light machine cut could be taken across the doublers to make a close tolerance

uniform thickness panel. Panels differed in corrugation depth as shown in

Figure 3-1(d). The shallow beads in the face skins were designed to relieve the

stresses caused by the thermal gradients. Heat treatment of the L605 and Rene' 41

panels were performed in two phases. For the first phase the panels were heated

in air, without any restraining fixtures, so that a high emittance oxide coating

would form on all surfaces. The panels were then clamped and heated a second time.

These coating and straightening operations were incorporated into the normal heat

treating sequence for the materials.

Testing consisted of exposing the structures to repeated cycles of simulated

mission environment. Each cycle consisted of exposure to assent pressure, entry

pressure and temperature, and cruise pressure, as shown in Figures 3-2(a) and (b)

for L605 and Rene' 41 panels respectively. Blocks of these cycles were followed

by blocks of acoustic test cycles.
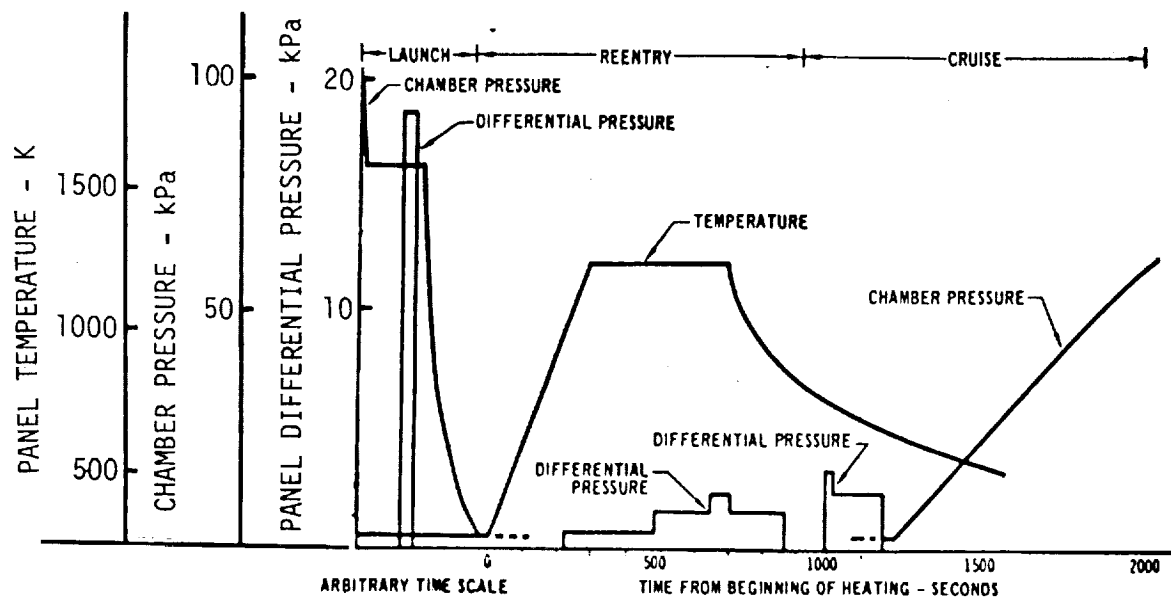
(a) L605 Panel
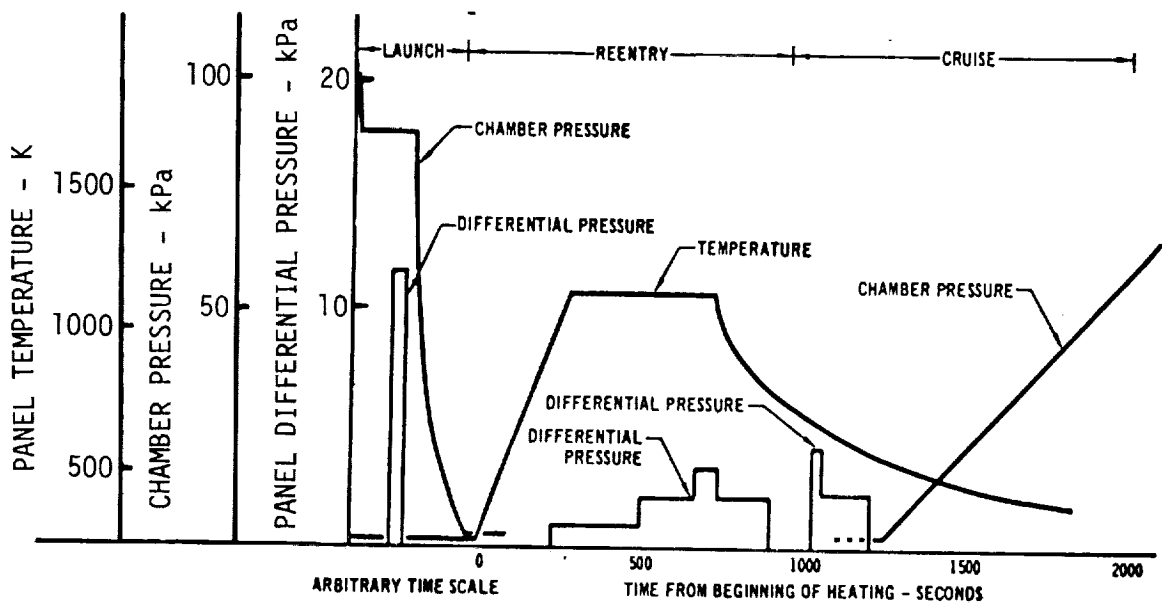
(b) Rene' 41 Panel

FIGURE 3-2 SIMULATED TEST MISSIONS USED IN SSTP PROGRAM

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

The programmed TPS differential pressure levels were met during the entry phase of the mission. Launch differential pressure levels were usually 35% low and cruise differential pressures were 50% low due to high TPS panel leakage. The Rene' 41 TPS panel was subjected to the complete 100 mission program, while the L605 panel was exposed to 30 temperature-pressure tests and 100 acoustic tests. Throughout each cycle the panel temperatures, not influenced by the joint, were controlled during heating. The cooling portion of the mission, however, was uncontrolled and in all cases cooled somewhat faster than expected. The lamp array used for heating the panels was made in sections creating an unavoidable gradient in the panels. Thermocouples were positioned so this gradient could be measured.

As part of the periodic inspections, the surface of the panels were mapped to detect any warpage or permanent set caused by the simulated missions. The aft panel on each of these assemblies deflected more than the forward panel. There was no obvious explanation for this difference, although it was probably caused by some phenomena associated with the test set-up. It is possible that the time at temperature for one panel was consistently slightly longer than the other.

The following sections describe the effort in evaluating data and in providing cyclic creep deflection predictions for these L605 and Rene' 41 TPS panels.

3.1.1 SSTP PROGRAM L605 PANEL

SSTP L605 temperature data (Reference 3) were reviewed to define actual panel temperature distributions which would be applicable to the panel analysis. The data points for several representative cycles are used in developing the temperature variations shown in Figure 3-3. As indicated in the referenced report, the influence of the lamp bank splice was approximately 30K (~50°F). Variation is noted between the panel edge and center temperature levels, however, no significant

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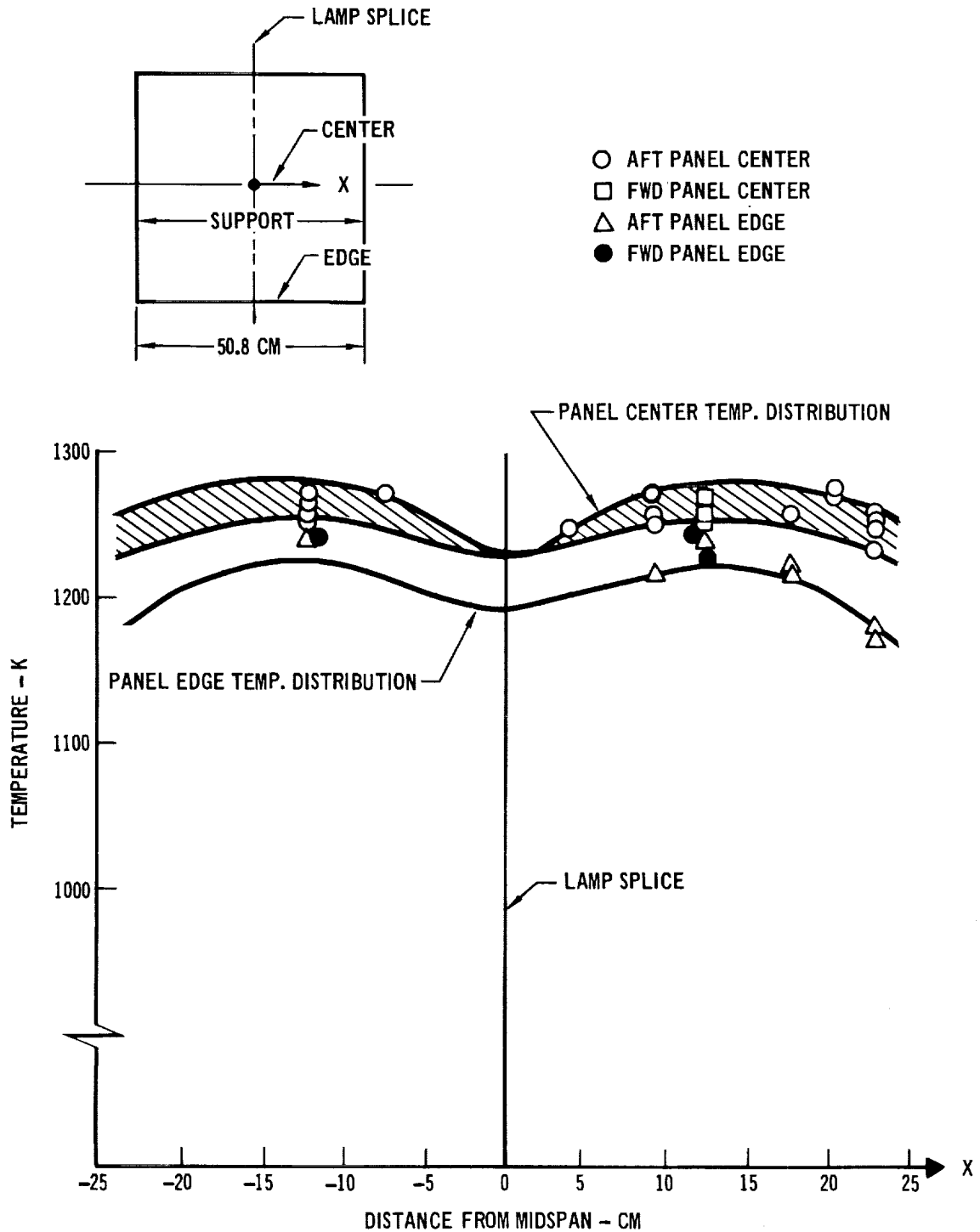
FIGURE 3–3 L605 TPS PANEL MEASURED TEMPERATURE DISTRIBUTIONS

3-6

difference can be detected between the forward and aft panels at either the center or edge locations.

Analysis of the panels was conducted for the reentry portion of the mission profile (Figure 3-2(a)). This profile was idealized into five constant temperature and differential pressure steps as indicated in Figure 3-4. Analysis was based on using the panel temperature distributions from Figure 3-3 defined as a function of time by the profiles in Figure 3-4.

Comparisons of creep deflection predictions with measured deflection data are presented in Figure 3-5. Considerable effort was given to evaluation of the creep deflection test data. A significant amount of variation was noted as indicated in the plots of Figure 3-5. Therefore, it is difficult to draw conclusions as to the prediction capability. A careful review of the reference 4 data did not reveal any differences which would account for the variation in deflection between the forward and aft panels as indicated in Figure 3-5(a). The prediction shown is based on the maximum of the temperature range shown in Figure 3-3 at the panel center. Analysis conducted using the minimum value of the temperature range resulted in approximately a 10% lower creep deflection prediction. The prediction shown for the panel edge in Figure 3-5(b) is based on the corresponding temperature distribution in Figure 3-3. Predicted deflections are based on the same unsupported span length (45.7 cm) and referenced measurement length (41.3 cm) as used in the SSTP Program. Data used in the analysis are presented in Tables 3-1(a), (b), and (c).
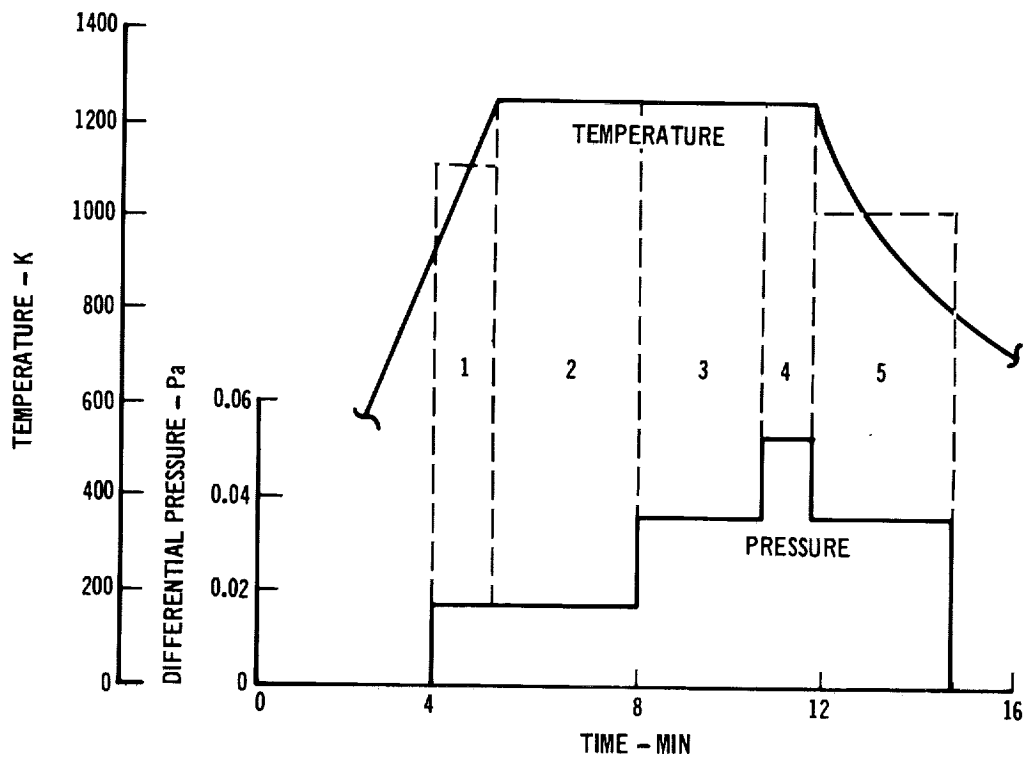
FIGURE 3-4 L605 ENTRY PROFILE USED IN CREEP PREDICTION ANALYSIS
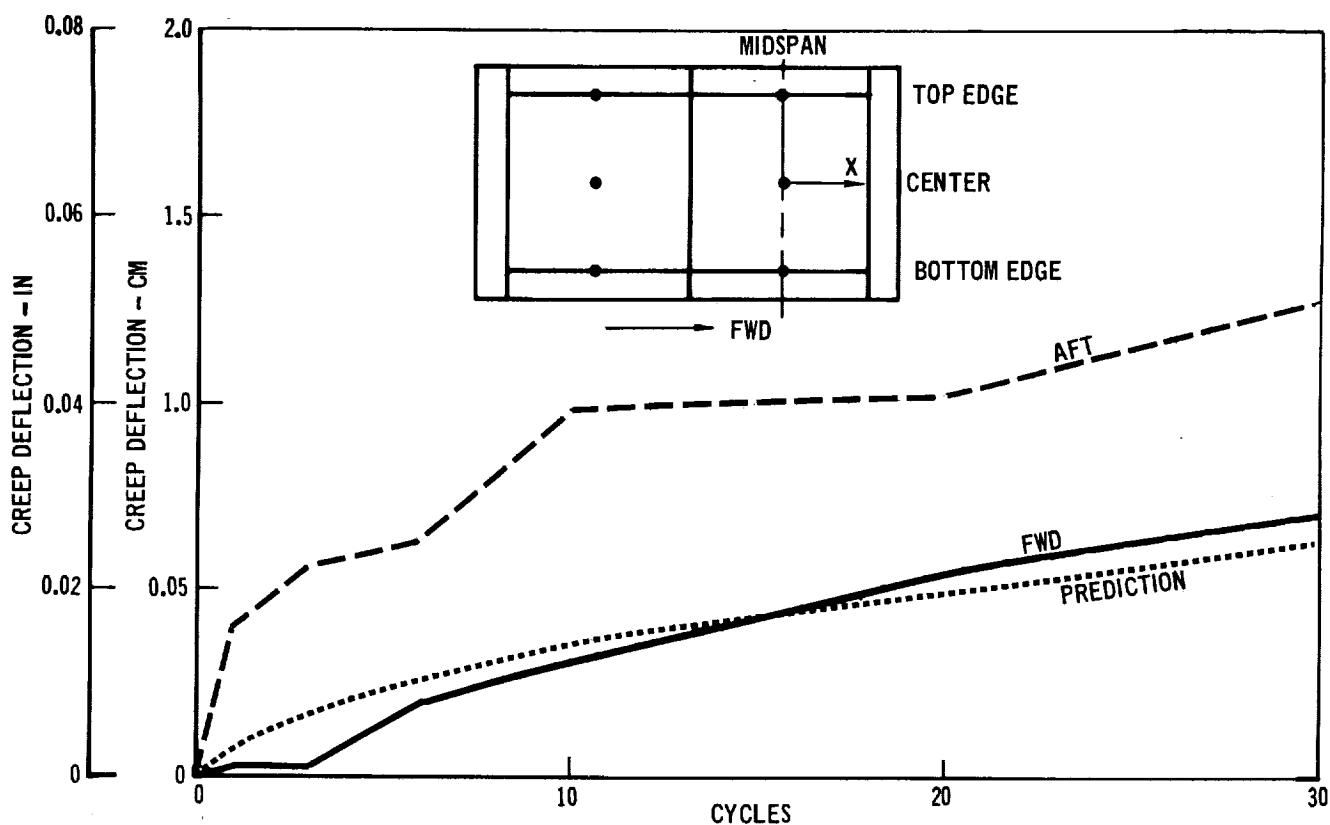
(a) Panel Midspan Deflections Along Center Span
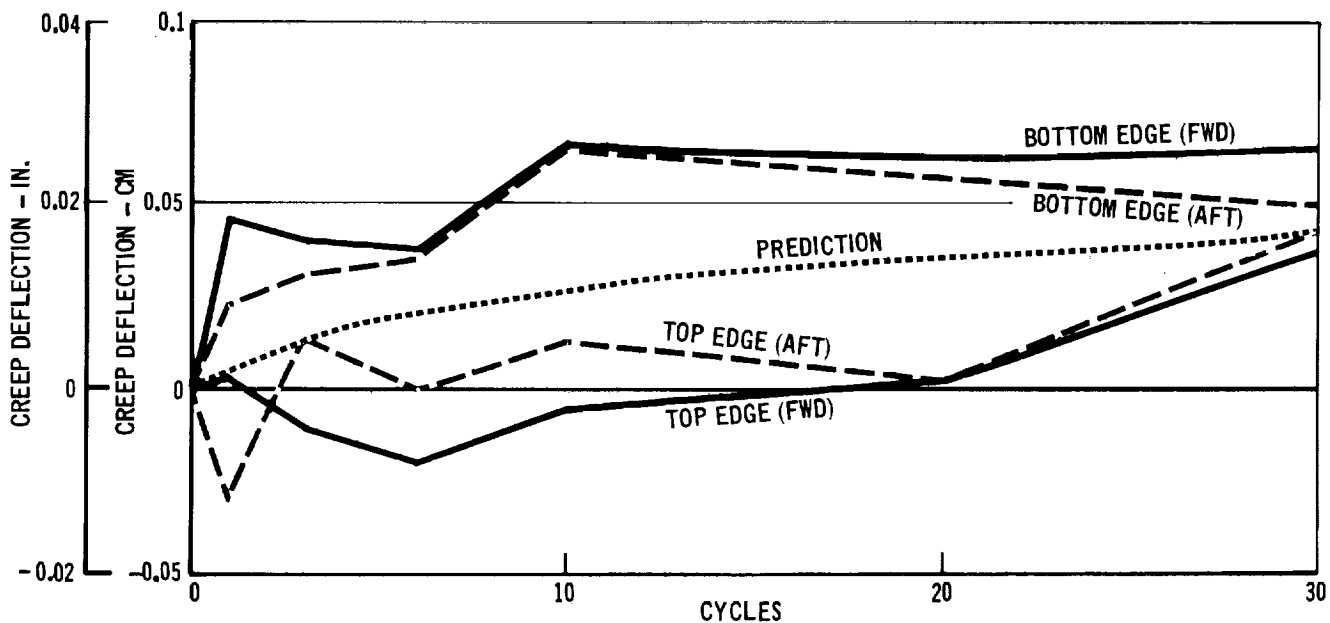
(b) Panel Midspan Deflections Along Edge

FIGURE 3-5 COMPARISON OF L605 PANEL TEST AND PREDICTED CREEP DEFLECTIONS

3-9

DEPTH =	1.85 cm (.729 in)
PHICOR =	12.63°
PITCH =	3.63 cm (1.43 in)
FLAT =	.71 cm (.28 in)
TS =	.0216 cm (.0085 in)
TC =	.0140 cm (.0055 in)
PANEL LENGTH =	45.7 cm (18. in)
BWID =	2.62 cm (1.03 in)
BDEP =	.28 cm (.11 in)
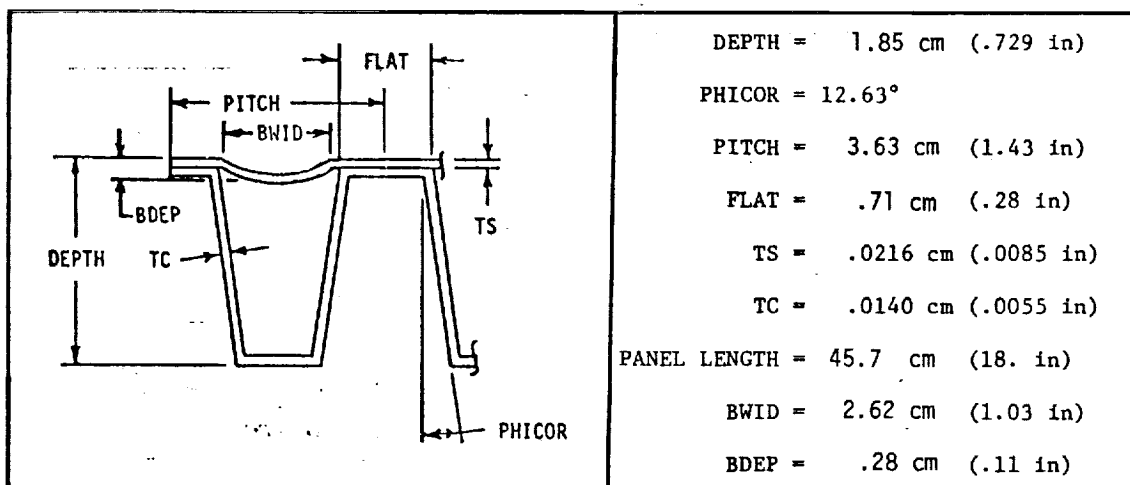
(a) L605 Panel Geometry

TIME (MIN)	PRESSURE KPa (PSI)	PANEL TEMPERATURE - K (°F)					
		X=0	X=5.1	X=10.2	X=15.2	X=20.3	X=22.9
0 - 1.33	.76 (.11)	1149 (1609)	1162 (1631)	1167 (1640)	1159 (1627)	1129 (1573)	1122 (1560)
1.33 - 4.67	.76 (.11)	1261 (1810)	1275 (1835)	1281 (1845)	1272 (1830)	1239 (1770)	1231 (1755)
4.67 - 7.50	1.65 (.24)	1261 (1810)	1275 (1835)	1281 (1845)	1272 (1830)	1239 (1770)	1231 (1755)
7.50 - 8.50	2.48 (.36)	1256 (1800)	1269 (1825)	1275 (1835)	1267 (1820)	1233 (1760)	1225 (1745)
8.50 - 11.33	1.65 (.24)	1038 (1408)	1048 (1427)	1053 (1435)	1046 (1423)	1021 (1377)	1014 (1365)

(b) Temperatures and Pressures Along Panel Center

TIME (MIN)	PRESSURE KPa (PSI)	PANEL TEMPERATURE - K (°F)					
		X=0	X=5.1	X=10.2	X=15.2	X=20.3	X=22.9
0 - 1.33	.76 (.11)	1076 (1476)	1108 (1534)	1115 (1547)	1108 (1534)	1090 (1502)	1088 (1498)
1.33 - 4.67	.76 (.11)	1178 (1660)	1214 (1725)	1222 (1740)	1214 (1725)	1194 (1690)	1192 (1685)
4.67 - 7.50	1.65 (.24)	1178 (1660)	1214 (1725)	1222 (1740)	1214 (1725)	1194 (1690)	1192 (1685)
7.50 - 8.50	2.48 (.36)	1173 (1651)	1209 (1716)	1217 (1731)	1209 (1716)	1194 (1681)	1187 (1676)
8.50 - 11.33	1.65 (.24)	973 (1291)	1001 (1341)	1007 (1353)	1001 (1341)	986 (1314)	985 (1310)

(c) Temperatures and Pressures Along Panel Edge

TABLE 3–1. GEOMETRY AND LOADING DATA USED IN L605 PANEL ANALYSIS

3–10
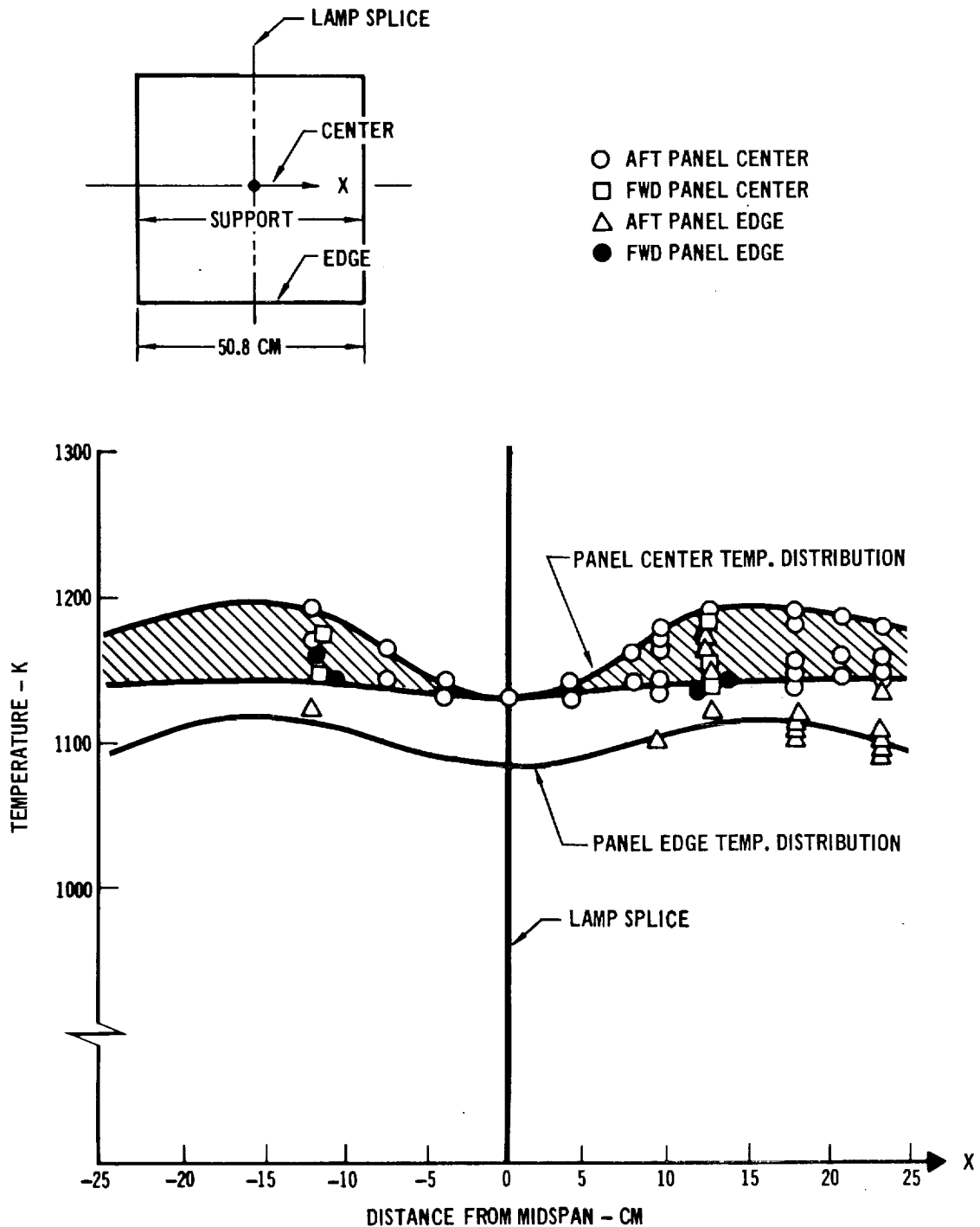
FIGURE 3-6 RENE'41 TPS PANEL MEASURED TEMPERATURE DISTRIBUTIONS

Initial analysis using a five time step idealization of the temperature and

load profiles (reference Figure 3-4 for L605) indicated that less than 2 percent

of the creep deflection occurred during the first and last time steps due to lower

temperatures than in the other three steps. Therefore, subsequent analysis for

Rene' 41 panels was conducted using the three step idealization of the entry

test profiles as shown in Figure 3-7. The first step at constant peak temperature

was extended in this case by approximately one half minute to compensate for the

deleted two steps.

Comparisons of predicted panel deflections with test data are provided in

Figure 3-8. Three predicted deflection curves are shown for the panel midspan

(Figure 3-8(a)). The two curves of highest predicted creep deflection (designated

A and B) are based on constant panel temperatures of 1144K (1600°F) and 1128K

(1570°F) corresponding to the trajectory profile (Figure 3-7) temperature and the

minimum panel center temperature distribution (Figure 3-6), respectively. These

two analyses show the effect of this temperature variation on the predicted creep

deflections. Both of these predicted curves are based on skin and corrugation

gages of .0216 cm (.0085 in) and .0140 cm (.0055 in), respectively.

In an effort to demonstrate the effect of gage effects on the creep deflection,

a third analysis was conducted (curve C) using the skin and corrugation gages of

.0254 cm (.0100 in) and .0178 cm (.0070 in). The constant temperature of 1128K

(1570°F) was applied, allowing comparison with the corresponding predicted deflec-

tion presented for the thinner gages (curve B). Again considerable variation was

evident in the deflection data for the forward and aft panels tested. Shown in

Figure 3-8(b) is the predicted creep deflection based on the panel edge tempera-

ture distribution defined in Figure 3-6. The panel dimensions, loads, and

temperatures used in the analysis are defined in Table 3-2(a), (b), and (c).
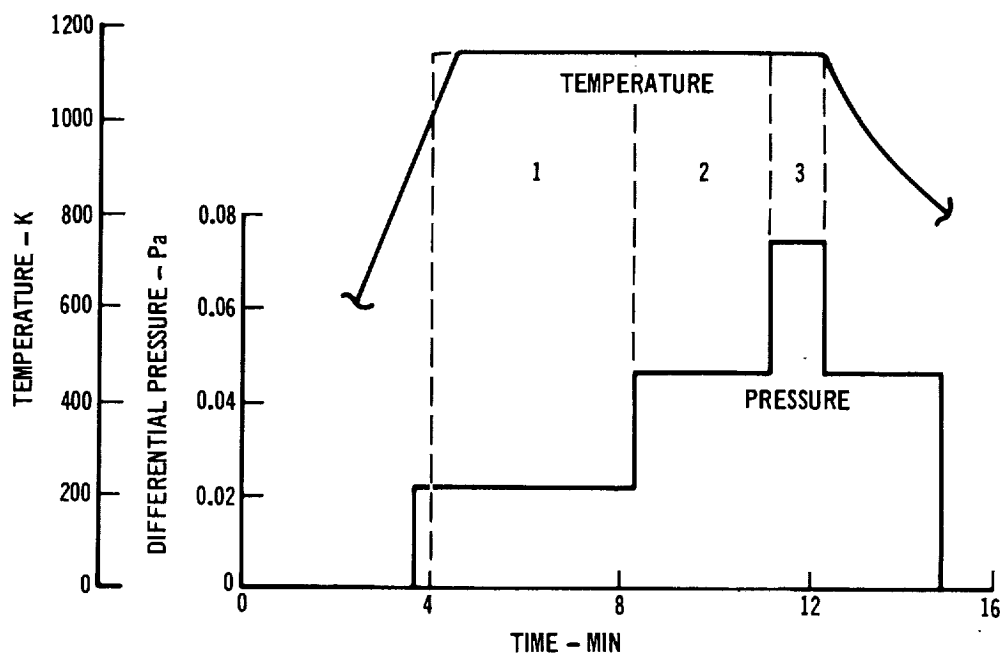
FIGURE 3−7 RENE'41 ENTRY PROFILE USED IN CREEP PREDICTION ANALYSIS
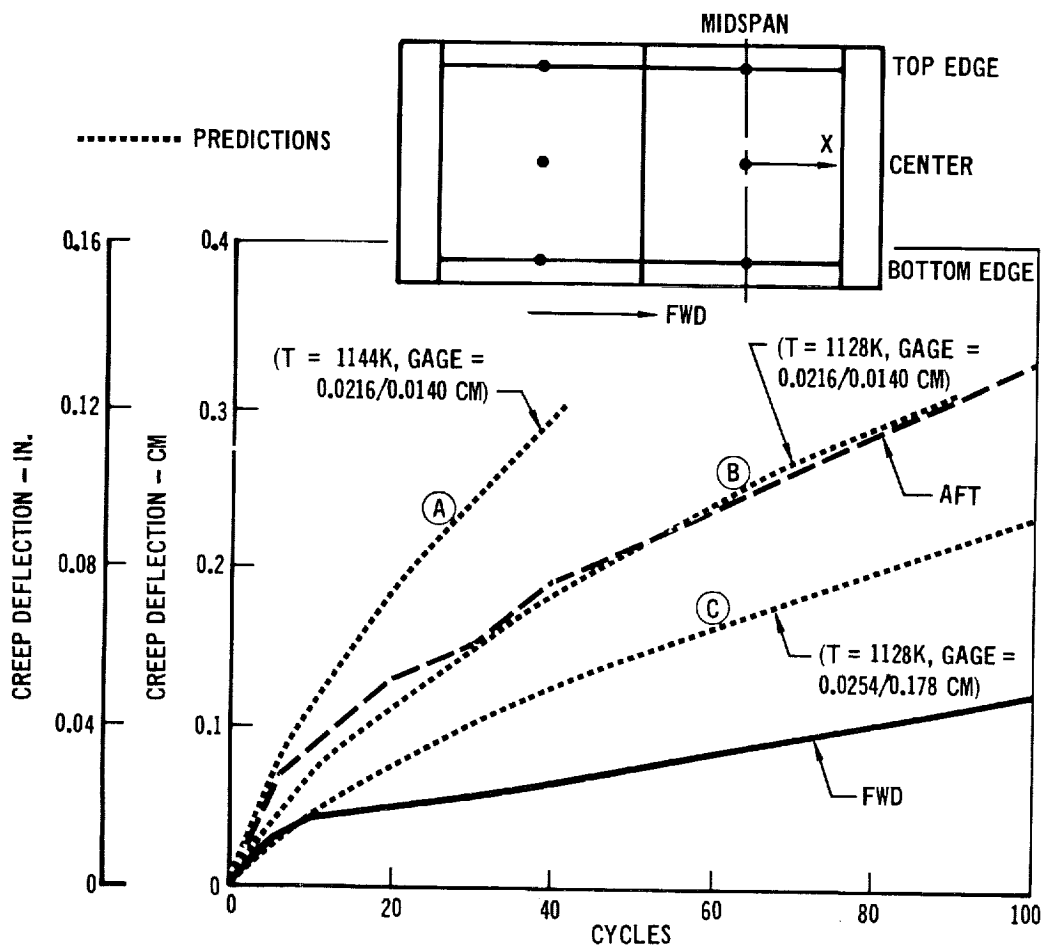
(a) Midspan Deflections Along Center Span
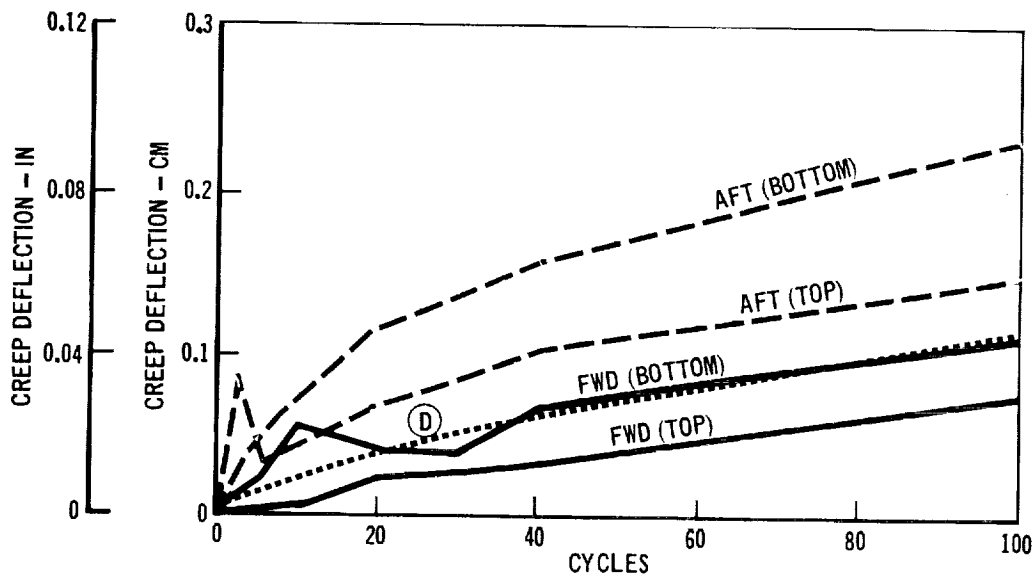
(b) Panel Midspan Deflections Along Edge

FIGURE 3-8 COMPARISON OF RENE'41 PANEL TEST AND PREDICTED CREEP DEFLECTIONS

DEPTH = .97 cm (.38 in)

PHICOR = 35.1°

PITCH = 3.63 cm (1.43 in)

FLAT = .71 cm (.28 in)

CURVE (C) { TS = .0254 cm (.0100 in)
            TC = .0178 cm (.0070 in)

CURVES (A)(B)(D) { TS = .0216 cm (.0085 in)
                   TC = .0140 cm (.0055 in)

PANEL LENGTH = 45.7 cm (18. in)

BWID = 2.62 cm (1.03 in)

BDEP = .28 cm (.11 in)
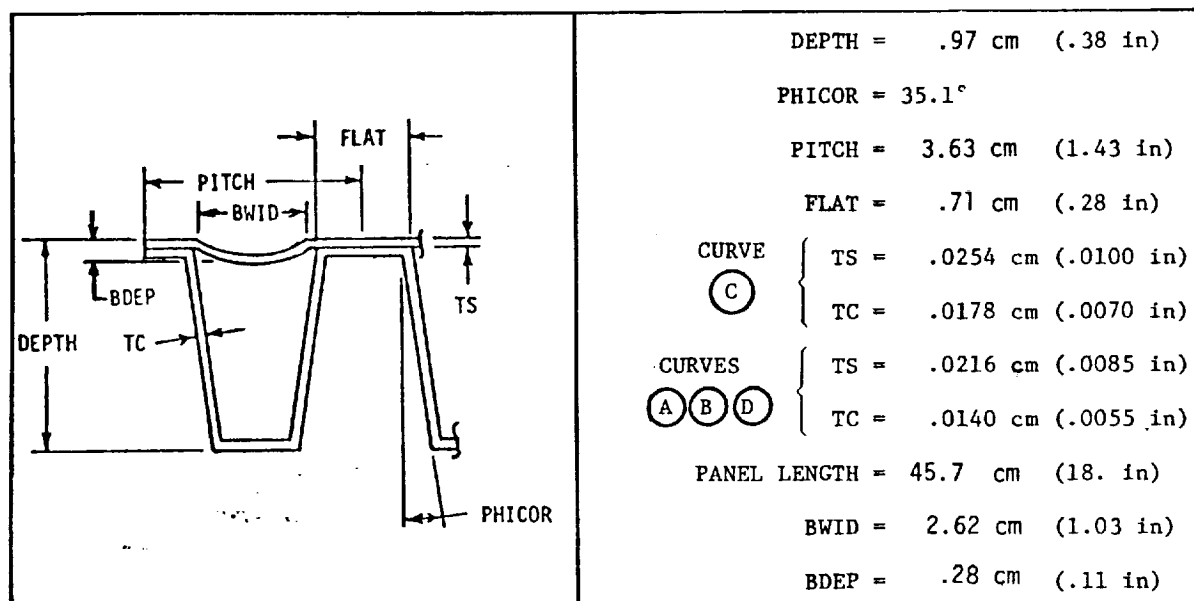
(a) Rene' 41 Panel Geometry

TIME (MIN)	PRESSURE KPa (PSI)	TEMPERATURE (CONSTANT ALONG LENGTH)		
		CURVE (A) (FIG. 3-8)	CURVE (B) (FIG. 3-8)	CURVE (C) (FIG. 3-8)
0 - 4.2	1.03 (.15)			
4.2 - 7.0	2.20 (.32)	1144 K (1600 °F)	1128 K (1570°F)	1128 K (1570°F)
7.0 - 8.0	3.45 (.50)			

(b) Temperatures and Pressures Along Panel Center

TIME (MIN)	PRESSURE KPa (PSI)	TEMPERATURE ~ K (°F)					
		X=0	X=5.1	X=10.2	X=15.2	X=20.3	X=22.9
0 - 4.2	1.03 (.15)						
4.2 - 7.0	2.20 (.32)	1100 (1520)	1111 (1540)	1111 (1540)	1097 (1515)	1083 (1490)	1081 (1485)
7.0 - 8.0	3.45 (.50)						

(c) Temperatures and Pressures Along Panel Edge

TABLE 3-2. GEOMETRY AND LOADING DATA USED IN RENE' 41 PANEL ANALYSIS

3.2 GRUMMAN TDNiCr PANEL

Evaluation of TDNiCr, from the standpoint of creep deflections in TPS panels, represents a different case than the other TPS materials because relatively little creep is evident in this material before failure occurs. Because of these low creep strains and resulting low test panel deflections, the data have tended to exhibit a greater amount of scatter.

The TDNiCr panel data evaluated in this section were obtained from Reference 8. The TPS panel tested consisted of a corrugation stiffened TDNi-20 Cr metallic heat shield backed by a flexible fibrous quartz and radiative shield insulation system. The test article represents the intersection of two 50.8 cm (20 inch) square panels as shown in Figure 3-9. Each panel consists of a beaded 0.025 cm (.010 inch) skin and corrugation. Detail dimensions of the corrugation cross section, used in analysis for panel deflections, are presented in Figure 3-10.

These panels were tested to 90 cycles of combined pressure and temperature loading, simulating critical heating and aerodynamic pressure environments expected during repeated missions of a reentry vehicle. Prior to these 90 cycles, the panels were subjected to 10 cycles of heating conditions only. Typical thermal distributions determined during these cycles are included in Figure 3-9 at various locations on the panels.

Entry test profiles (Reference 8) and idealizations used in the analysis are shown in Figure 3-11. For purposes of analysis these profiles were idealized into the three constant load and temperature steps shown. These temperatures were assumed to be constant along a panel length of 47. cm (18.5 in.). Analysis of the corrugation panel geometry under the idealized loads and temperature profiles was conducted using the analytical methods developed in Phase II (Reference 2). The empirical creep strain equation (Table 2-1) developed in Phase I, was used in the

3-16
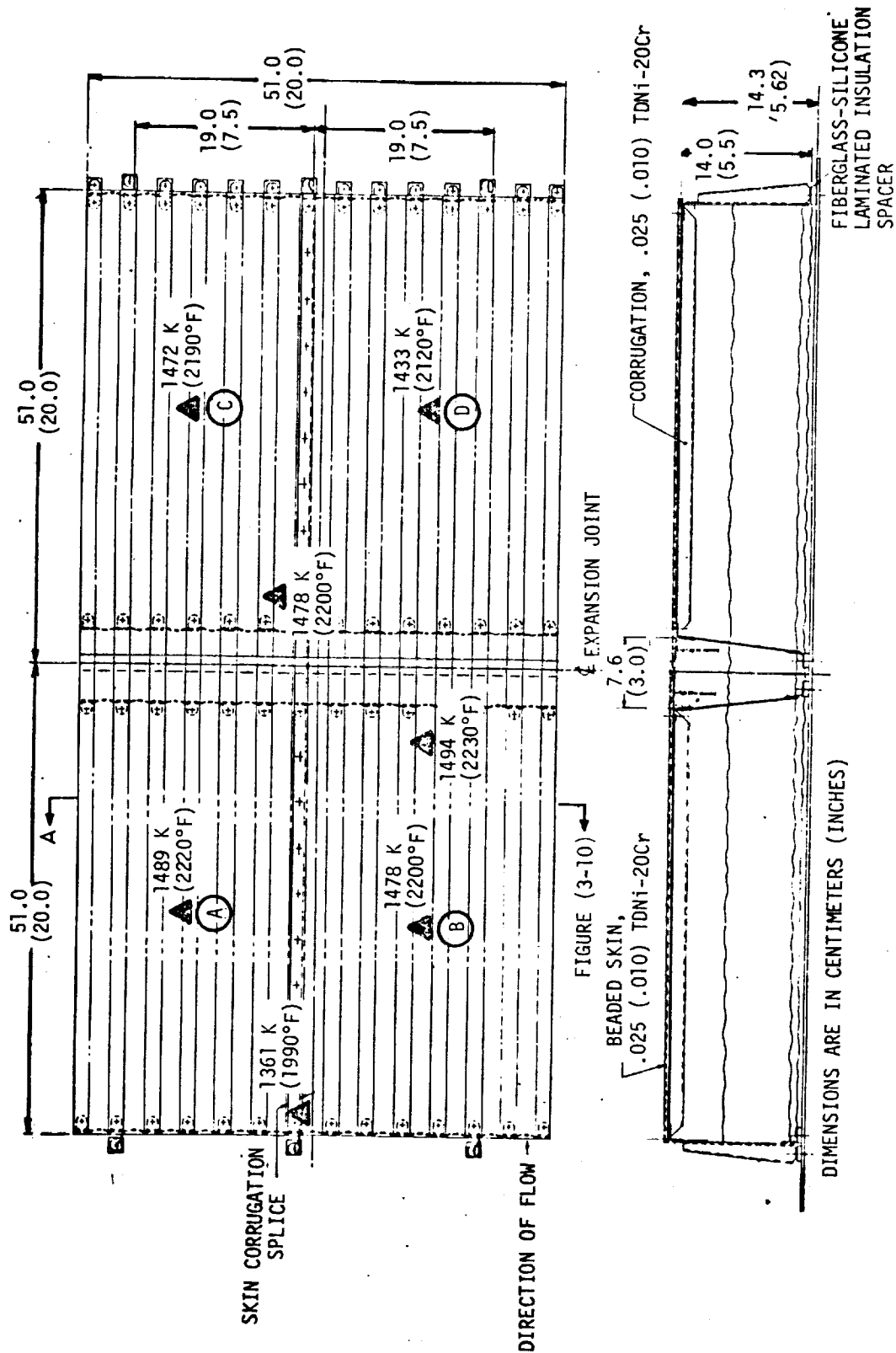
FIGURE 3-9 GRUMMAN TD NiCr TEST PANEL SETUP
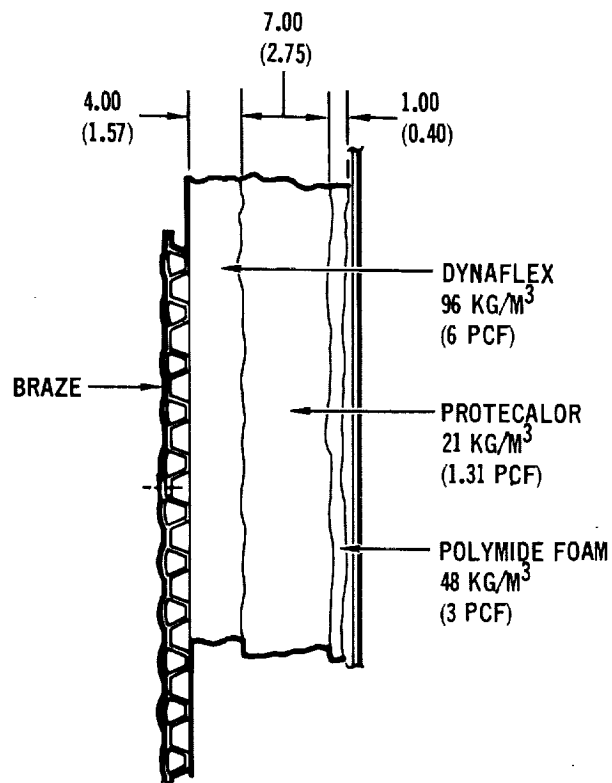
Section A – A (Figure 3 –9)
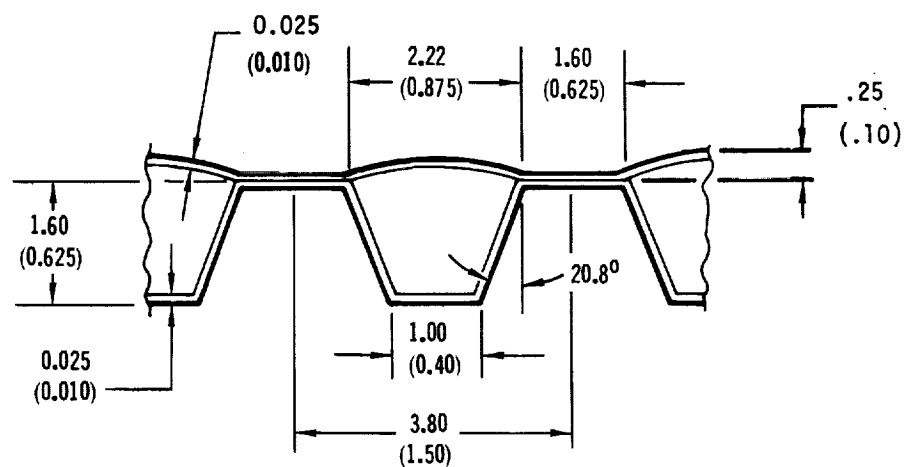
FIGURE 3–10 TDNi Cr TEST PANEL CORRUGATION DEFINITION
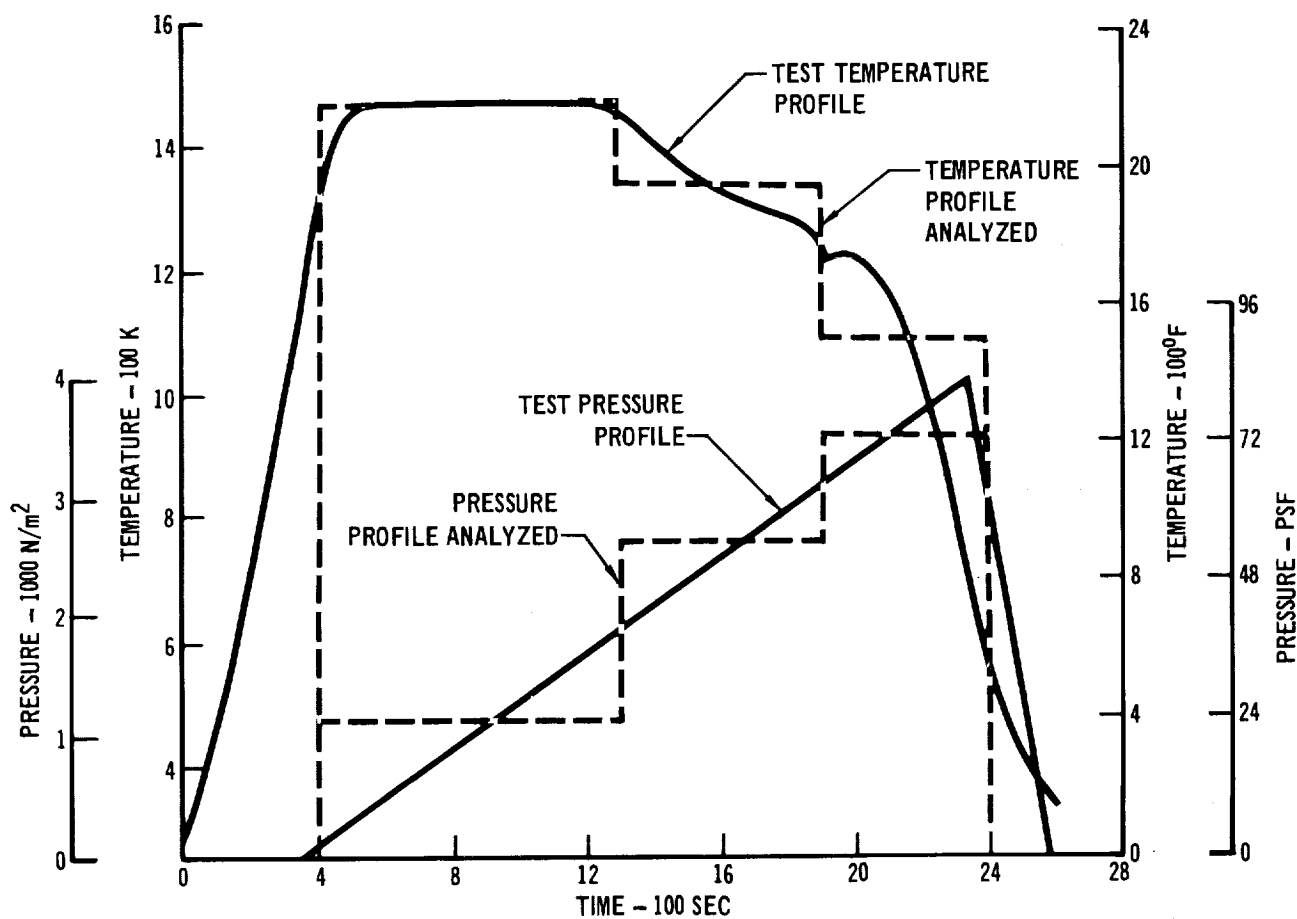
FIGURE 3-11 TEST AND IDEALIZED LOADING AND TEMPERATURE PROFILES

analysis to represent the material creep strain response and the time hardening

theory of creep accumulation was applied.

Shown in Figure 3-12 are comparisons of the predicted creep deflections with

measured permanent test deflections. The test deflections are plotted from

initiation of the combined load and temperature cycles for four midspan locations

referenced to the panel geometry in Figure 3-9. A significant variation is noted

in these test data. In the reference 8 report the variation was attributed to the

slightly higher temperatures observed at locations A and B. In addition it was

noted that there was a significant increase in permanent deflection at locations

C and D, between cycles 1 and 9. This was attributed to residual stresses, built

into the panel during manufacture and assembly as well as thermally induced loads.

Therefore, there remains some question as to the true amount of creep occurring

between cycles 1 and 9.

The predicted creep deflections indicate a lower rate of creep than observed

in testing. This is attributed to the empirical equation in the stress and

temperature range applied. The analysis showed that approximately 75% of the

creep occurred during the first load-temperature step in the profile (Figure 3-11).

Temperature during this step was 1478K (2200°F) and calculated corrugation outer

fiber stress was approximately 23 MPa (3300 psi). Comparison of Phase I cyclic

tensile creep data with the empirical equation predictions shown in Figure 2-4

also indicate the lower slope of the predicted strains. The wide variation in

creep deflections cannot be predicted, based on the temperature data.
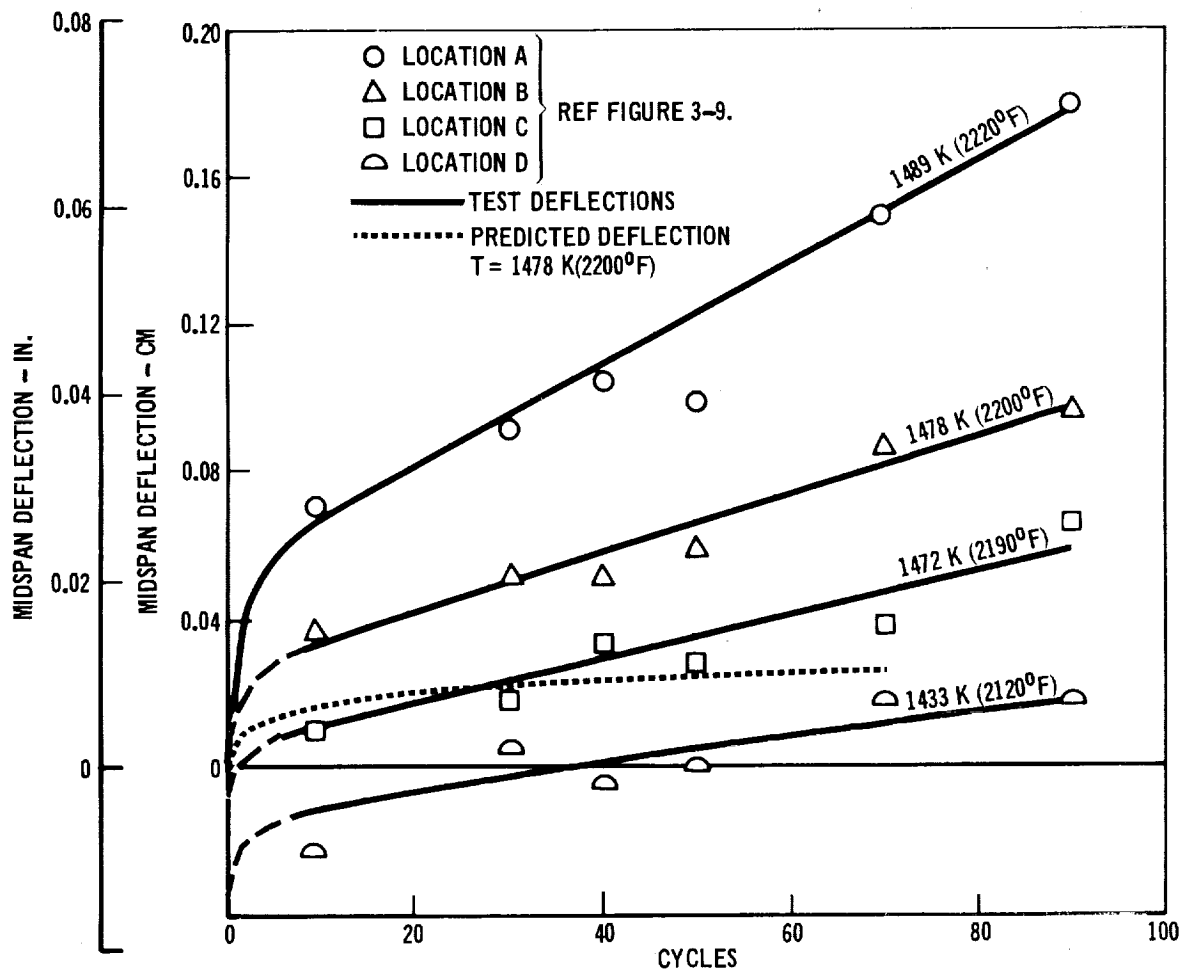
FIGURE 3−12 COMPARISON OF TD NiCr PANEL TEST DEFLECTIONS
AND PREDICTIONS

3.3 GRUMMAN HAYNES 25 PANEL

A Haynes 25 (L605) panel was tested by Grumman Aerospace Corporation and
results presented in References 6 and 7. The panel tested was designated as panel
No. 3 in the references and was segmented, as shown in Figure 3-13, into four
separate test panels. The cross section geometry was single face corrugation
stiffened with a skin bead of approximately 0.25 cm (0.10 in.) depth. These
panels were supported at the ends (simple support assumed for analysis) over a
47.2 cm (18.6 inch) span and subjected to a uniform pressure profile of 2.42 kPa
(0.35 psi). The temperature profile used in the cyclic testing is presented in
Figure 3-14. Also shown is the two step idealized temperature profile used in
the analysis. Panel geometry and dimensions used in the analysis are provided in
Figure 3-13. For each of the panels, analysis was conducted for two different
temperature levels because of the cycle to cycle test temperature variations as
indicated in Figure 3-15. The time hardening theory of creep accumulation was
applied in conjunction with the L605 cycle creep empirical equation (Table 2-1)
developed in Phase I.

Comparison of resulting predictions with the Reference 6 experimental data,
shown for the NE and SW panels in Figure 3-16(a) and (b), respectively, show that
the experimental deflections are considerably higher than predicted. No explana-
tion of this variation between theory and test has been determined based on the
data in the reference.

CLOSURE MEMBER

PANEL SPLICE

INSULATION

TPS PANEL
(HS-25)

STAND-OFF

INSULATION
(MICROQUARTZ AND
INCONEL FOIL)

DRAG BRACE

2.42 kPa (.35 PSI)

47.2
(18.6)

.25
(.10)

2.5
(1.0)

.63
(.25)

1.59
(.625)

.025
(.010)

11.3°

.020
(.008)

1.90
(.75)
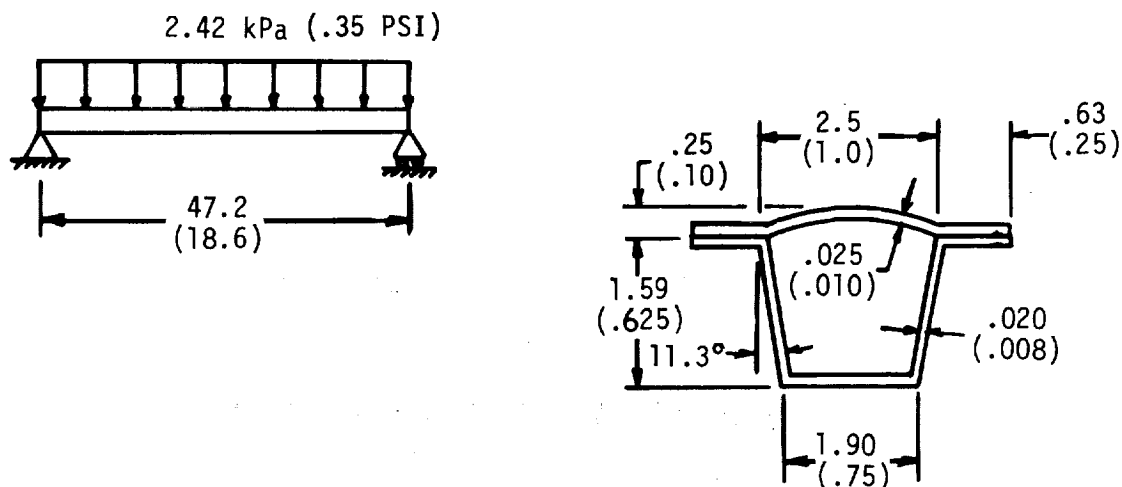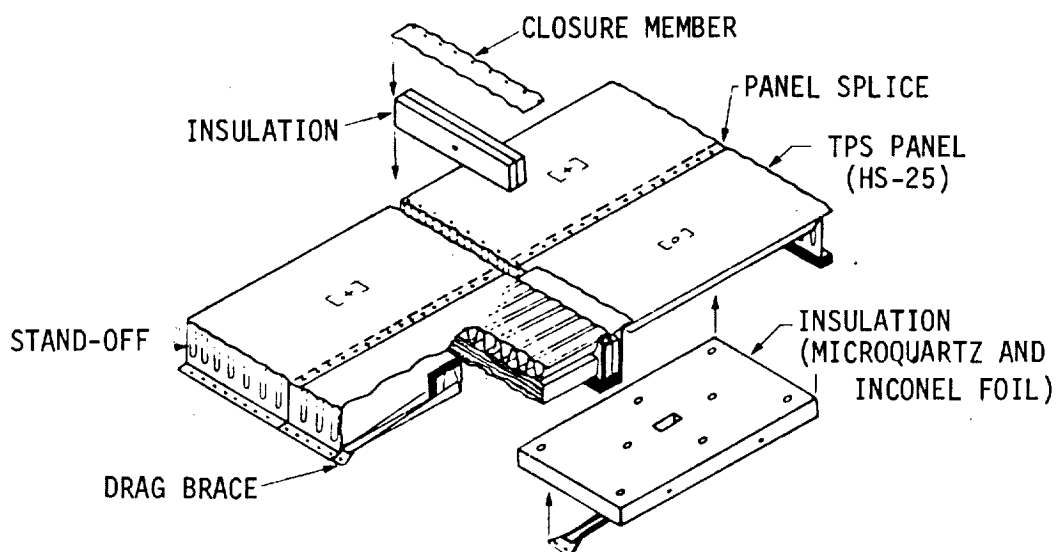
DIMENSIONS ARE CENTIMETERS (INCHES)

FIGURE 3-13 PANEL GEOMETRY FOR GRUMMAN HAYNES 25 PANEL TESTS
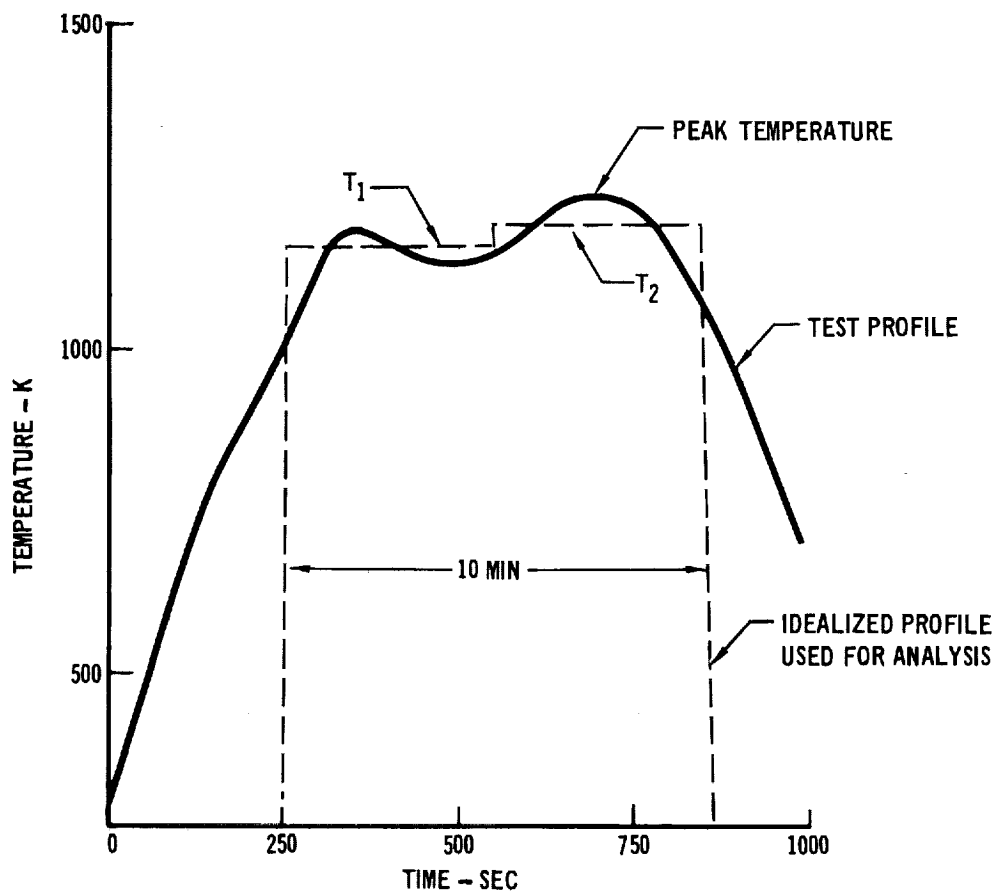
FIGURE 3-14 HAYNES 25 PANEL TEMPERATURE PROFILE

3-24
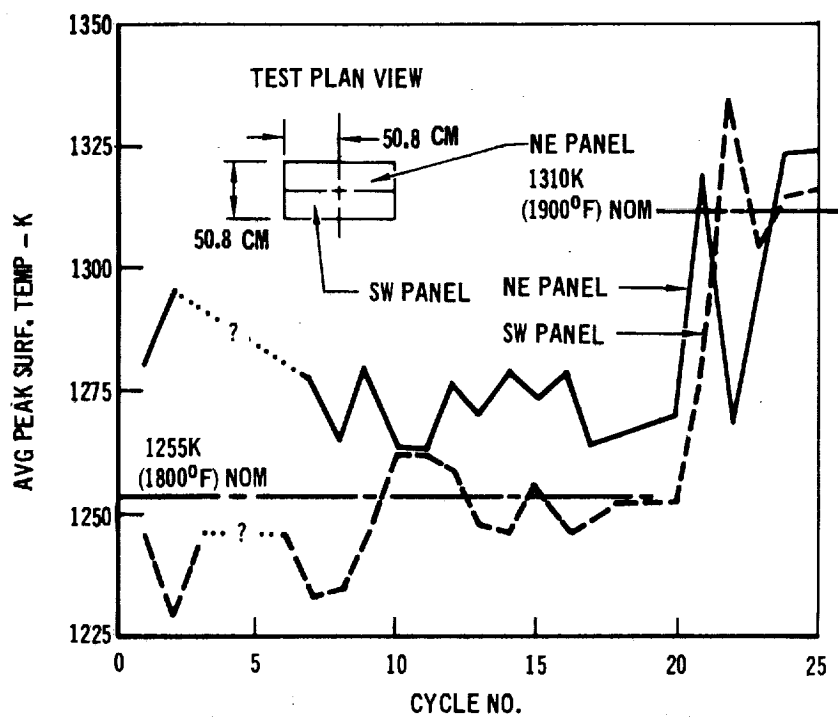
FIGURE 3-15 HAYNES 25 PANEL AVERAGE PEAK MEASURED TEMPERATURE
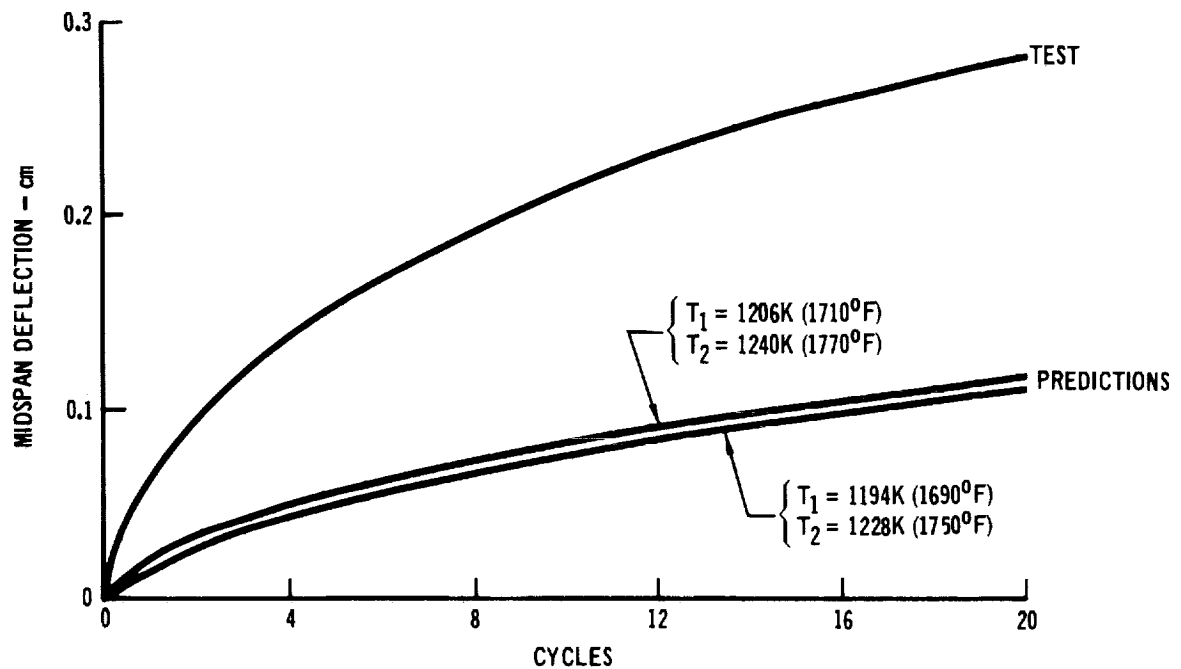
(a) NE Panel
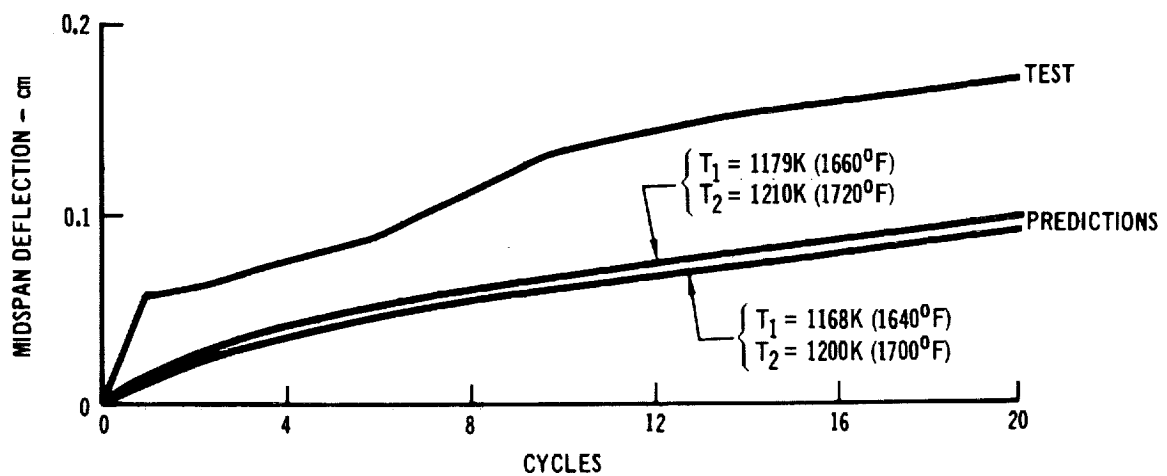
(b) SW Panel

FIGURE 3-16 COMPARISON OF PREDICTED CREEP DEFLECTIONS WITH
TEST DATA FOR HAYNES 25 PANELS

3-26

4.0 PHASE III CONCLUSIONS

Comparison of permanent cyclic creep deflections, obtained in testing of full size thermal protection system panels, with predicted values has met with varied degrees of success. Prediction capability for L605 and Rene' 41 appears to be reasonably good, although there is much variation in the test data, even for panels tested simultaneously to the same temperature and load level. Prediction capability for TDNiCr appears to be less accurate although recognition of the low creep rate of TDNiCr has led to minimization of effort on creep response definition throughout the program. Predictions for the full size panels are summarized in Table 4-1, showing that prediction accuracies cannot, in general, be expected to be better than a factor of two. These predictions were made using the time hardening theory of creep accumulation.

Resulting predictions of cyclic creep deflection have been shown to be sensitive to both stress level and temperature. This makes prediction capability more difficult since variations from cycle to cycle were known to occur but may not have been defined for each cycle. Such factors as an overshoot in temperature for only one cycle or a few cycles could significantly increase the total test deflections attained. In addition, the test panels were generally subjected to other environments such as high launch phase loading and acoustic environments, which possibly contribute to redistribution of panel relative displacement and variation in the data.

TABLE 4−1. SUMMARY OF FULL SIZE PANEL CREEP DEFLECTIONS

TEST PANEL		RANGE OF TEST DEFLECTIONS Cm	PREDICTION Cm	PREDICTION AS % OF TEST AVERAGE
L605 (Sec. 3.1.1)	CENTER	.071 − .127	.064	64%
30 Cycles	EDGE	.036 − .066	.043	85%
Rene' 41 (Sec. 3.1.2)	CENTER	.127 − .330	.033	144%
100 Cycles	EDGE	.076 − .239	.114	73%
TDNiCr (Sec. 3.2) 50 Cycles		.013 − .305	.064	40%
Haynes 25 (Sec. 3.3) 20 Cycles		.170 − .290	.100−.120	48%

5.0 THERMAL PROTECTION SYSTEM DESIGN CRITERIA

During the course of Phases I, II, and III of this program several factors affecting creep of metallic TPS and considerations in the design and analysis of metallic TPS have been identified. During Phase I (Reference 1) tensile creep testing was conducted on L605, Ti-6Al-4V, Rene' 41, and TDNiCr specimens under both steady state and cyclic loading and temperature conditions. Test matrices were established to provide maximum data throughout the temperature, stress, and strain range of interest with a minimum number of tests. Resulting data were analyzed to provide empirical equations expressing both steady state and cyclic creep strain as a function of temperature, stress, and time. Additional tests were conducted to evaluate other factors influencing cyclic creep strain such as the applicability of creep accumulation theories and effects of test time per cycle and material thickness. During Phase II (Reference 2) methods were developed for predicting creep deflections of thin gage metallic thermal protection system panels subjected to complex temperature and loading environments. Subsize panels, fabricated from the same material as used in Phase I, were tested to provide data for analysis verification. In the analysis of these data, factors such as sensitivity of the prediction to temperature variations were studied and expected accuracies were noted. Analysis of full size TPS panel test data in Phase III provided additional insight into expected analysis accuracies.

This section summarizes program results in a format which can serve as a criteria in accounting for creep in the preliminary design of metallic thermal protection systems. In addition to specific information obtained on this program, applicable experience based on results from other programs felt applicable to creep of TPS is also included.

5.1 GENERAL CONSIDERATIONS

Critical Design Conditions

TPS panels must first be sized based on strength and stiffness considerations over the entire range of flight conditions. The material choice is dictated by the peak temperatures occurring during entry. Critical design conditions have generally been found to be peak pressure loads and acoustic loadings occurring at relatively low temperatures during ascent or cruise conditions. Envelopes of panel strength and flight conditions such as that demonstrated in Figure 5-1 are helpful in visualizing the critical conditions for these panels. The example shows the panel to be critical during cruise where the peak pressure is applied at low temperatures. The panel strength then exceeds requirements throughout the remainder of the mission.

Panel Deflections

Deflections which must be considered are elastic deflections of the panel under applied differential pressure loads, thermal deflections which result from temperature gradients through the panel depth, and permanent creep deflections which accumulate throughout the life of the TPS panel. Various allowable deflections have been established such as those in References 9 and 10 which are shown in Equation (1) and (2) respectively.

$$\delta = .25 + .01L \text{ cm} \tag{1}$$

$$\delta = .25 + .04L \ [(B.S.-30.5)/280] \text{ cm} \tag{2}$$

where B.S. = VEHICLE BODY STATION

These equations provide for maximum deflections of .75 cm and 2.25 cm (@ B.S.=787 cm (310 in)), respectively for a 50 cm (20 inch) long panel. Allowable total deflections must be established for each system based on the thermodynamic and aerodynamic requirements.

5-2
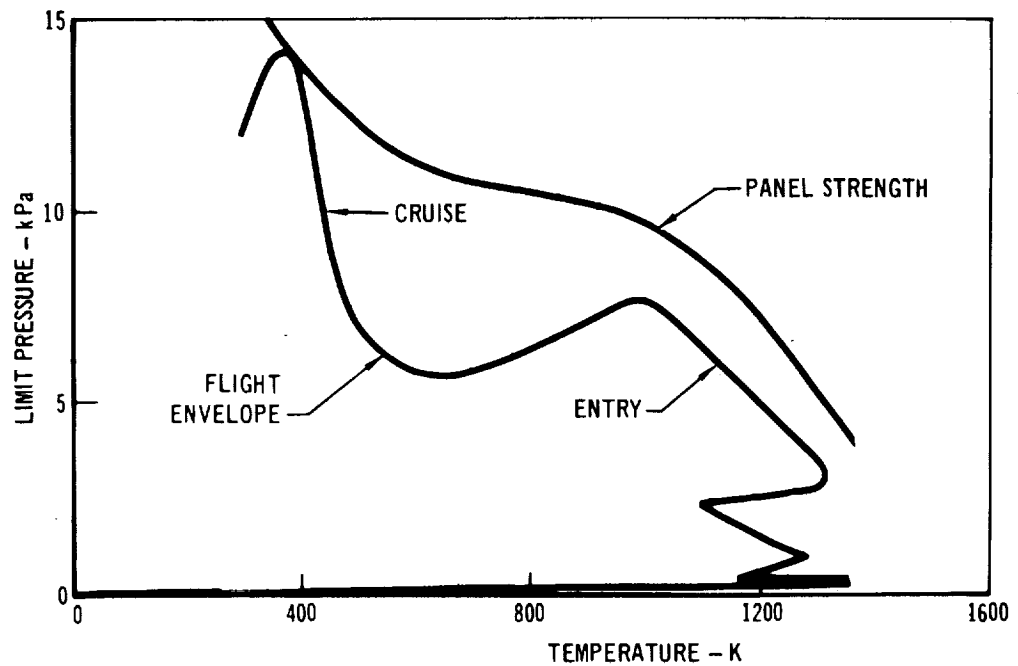
FIGURE 5−1 L 605 PANEL STRENGTH FOR FLIGHT ENVELOPE

The relative importance of thermal deflection has generally not been assessed in past studies. These deflections will be zero during steady state conditions where temperatures are uniform through the panel depth. During heating, when the maximum temperature occurs on the outer surface of the panel, the deflections will be in the opposite direction from the elastic and accumulated creep deflections.

Panel Replacement and Inspection

In the context of panel deflections, a failure will be an excessive deflection which requires panel replacement. Requirements for the panel design deflections will result from trading off refurbishment cost against any weight penalty which might result from the necessity to resist creep deflections.

It is expected that panels in one area of the vehicle might creep much faster than in other areas due to particular mission maneuvers, etc. Therefore, replacement of same panels may be required after each mission. It does not seem to be desirable or possible to optimize these panels from the standpoint of deflection over the entire vehicle since the mission requirements will provide considerable variation in applied loadings from one mission to another and from one location to another location on the vehicle. Visual inspection with spot centerline measurements, using a simple bar/dial gage tool would be sufficient to detect excessive deflections.

5.2 DESIGN CONSIDERATIONS – THERMAL EXPANSION

One of the primary considerations in the design of TPS panels is that the panel be allowed to expand freely under thermal loadings. Allowances must be made for thermal expansion both at the panel joints and on the panel surface.

Expansion is generally accomplished at the joints by fixing the panel at one end and allowing it to slide longitudinally at the other end. Transverse deflections are accomplished by slotted holes at both attachment locations and by

providing for expansion in the longitudinal joints between adjacent panels. Typical designs can be found in References (3) and (11).

Temperature variations along the panel length due to the heat sink at the panel support cause thermal stresses in the transverse direction. During heat up of the panel, the midspan is hotter than the edges at the supports causing compressive stresses at the center and tensile stresses at the edges. These stresses are reversed during cooldown.

The presence of beads relieves the thermal stresses and prevents thermal buckling (Reference 12) of the thin skin between stiffeners by allowing the skin to flex as thermal expansion occurs. Analysis can be used to define required bead depths. Particular attention should be given to the approach for closing out the bead near the panel ends. Testing (Reference 3) has shown that cracking can occur in the skin at the tips of the beads where the beads are transitioned into a flat skin. It would be desirable from this standpoint to extend the bead to the panel ends. This, however, complicates the design at the panel joints.

5.3 DATA REQUIREMENTS FOR CREEP ANALYSIS

During Phase I (Reference 1) testing was conducted under both steady state and cyclic conditions to evaluate the creep response characteristics of the materials studied and to provide data for use in the analysis for panel creep deflections. During these studies considerable effort was directed at obtaining the required test data.

Test Matrix - Basic Data Required

One of the objectives in evaluating creep deflections should be minimizing the required testing. However, it is of interest to cover the complete range of stress, temperature, time, and strain required to provide an adequate material response definition for use in the analysis. The analyst does not want to be in

the position where extrapolation of the available data is required.

The range of strain which is required will be dependent upon the criteria for allowable deflection used. As an example of possible calculations it could be assumed that creep deflections obtained in testing will be approximately 50% of those obtained using a linear creep stress-strain assumption. This assumption tends to account for the redistribution of beam stressed due to nonlinear creep strain-stress properties. The assumption is expressed in the following equation:

$$\frac{\Delta_c}{\varepsilon_c} = .5 \frac{\Delta_E}{\varepsilon_E}$$

where: Δ_E = BEAM midspan elastic deflection

ε_E = Maximum midspan elastic strain (extreme fiber)

Δ_c = Beam midspan creep deflection

ε_c = Maximum midspan creep strain (extreme fiber)

Applying this equation and assuming an elastic deflection based on a uniform pressure loading the following equation can be derived for creep strain at the beam midspan.

$$\varepsilon_c = \frac{2\Delta_c}{\Delta_E} \qquad \varepsilon_E = \frac{2\Delta_c}{\dfrac{5}{384}\dfrac{WL^4}{EI}} \qquad \frac{WL^2}{8\,EI}\overline{Y} = 19.2\,\frac{\Delta_c\overline{Y}}{L^2}$$

Where: W = Beam pressure load

L = Panel length

E = Elastic modulus

I = Panel moment of inertial

$\overline{Y}$ = Maximum distance from neutral axis to extreme fiber

For a full size panel of 50 cm length, Δ_c = .75 cm (based on .25 + .01L cm criteria), and $\overline{Y}$ = 1.5 cm, the required creep strain would then be .86%.

5-6

It is of interest to note that if this calculation was carried out for a shorter TPS panel, the creep strain required to attain the same creep deflection is higher because the strain is inversely proportional to the square of beam length. Therefore, use of a deflection criterion with subsize panels results in requirements for greater creep strains than would be attained in a full size panel under the same criterion.

Test matricies can be established on stress-temperature charts upon which approximate constant strain lines can be drawn. In the Phase I studies (Reference 1) these were based on evaluation of steady state literature survey data. Typical designs for the test matricies are shown in Figure 5-2 based on the Reference L605 evaluation. Requirements for the designs include:

(1) Test data should be amenable to development of an empirical creep strain equation. Applicability of each design for satisfying this requirement can be checked by generating simulated creep strain data using an available equation, performing regression analysis, and evaluating the resulting prediction equation.

(2) Test temperatures should cover the range of interest for the material being tested.

(3) Test temperatures and stress levels should produce creep strains in the range of interest.

The designs shown in Figure 5-2(a) and (b) include a simple 3 x 3 factorial design and an orthogonal composite design. They are described in References 14 and 15. Although both designs satisfy the first requirement (1) above, they may satisfy the second or third requirements, in this case as indicated in the figure.

In addition to these two designs, the design shown in Figure 5-2(c) was also considered because it provides maximum coverage of the test temperature and stress range of interest. However, it was subsequently demonstrated that the resulting prediction equation, based on this design, was a function of time only.
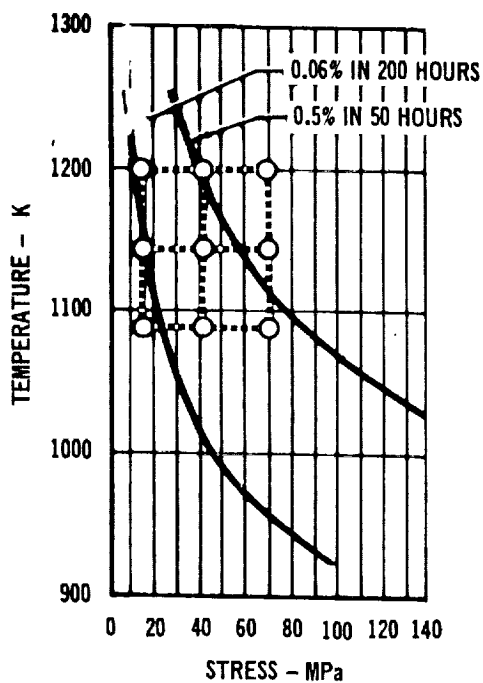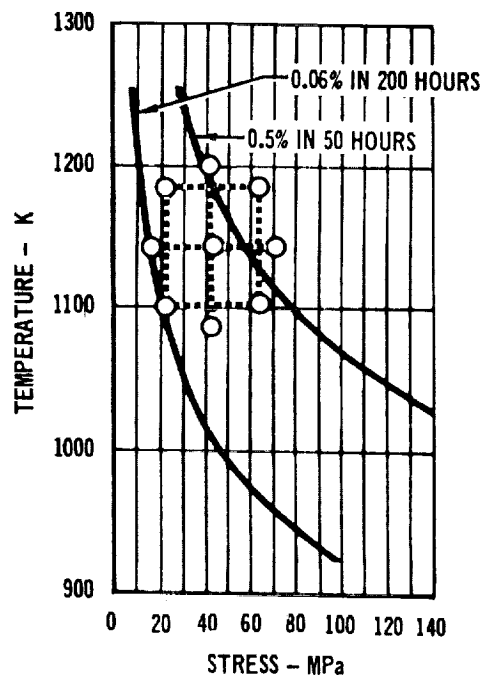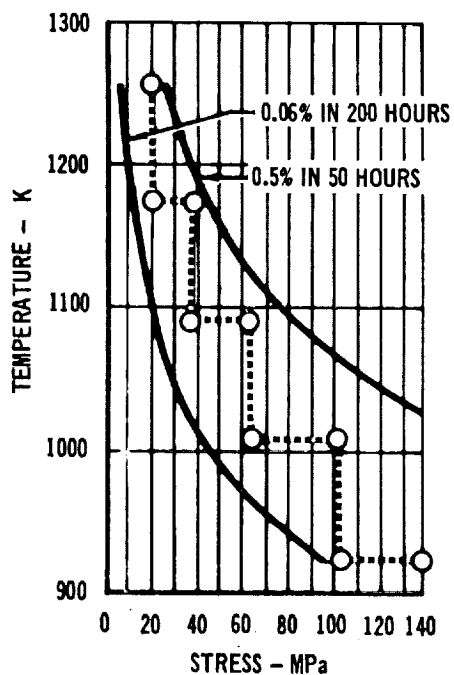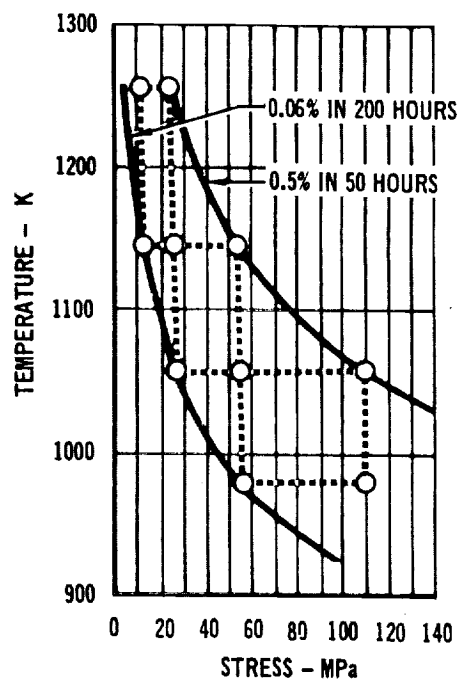
FIGURE 5-2 EXPERIMENTAL DESIGNS FOR CREEP TESTING

A fourth design considered is shown in Figure 5-2(d). This design allows testing over a wide stress and temperature range and evaluation of the design indicated that an empirical equation can be derived from the resulting data.

For the data range of interest in this program it was found that the design shown in Figure 5-2(d) was best.

The orthogonal composite design (Figure 5-2(b)) was, however, used in the Rene' 41 evaluation (Reference 1) where the lines of constant strain were found to be further apart on the stress temperature plot.

A study of proposed test designs is recommended, using applicable regression techniques, prior to conducting creep tests.

Determination of Empirical Equations

A very large number of equations are found in the literature which have been developed over the years to describe the complex physical process of creep. In addition, an infinite number of new relationships (or models) can be formulated.

The description of a new equation involves the determination of the relationship between the dependent variable, strain, and the independent variables, such as temperature, stress, time, thickness, and orientation. A convenient procedure for determining this relationship is the use of multiple regression techniques. Two parameters associated with this technique are (1) the multiple correlation coefficient, R, and (2) the standard error of estimate, S_y. The multiple correlation coefficient is a measure of how well the fitted equation explains the variation in the data (Reference 15). The closer the value of R^2 (or R) is to 1, the better the equation will fit the data. The standard error of estimate is an estimate of the variance about the regression line. Therefore, the precision of the estimate would be considered better the lower the value of S_y. Accordingly, in the development of the various regression equations that were examined during

the program, emphasis was placed on obtaining equations which resulted in large

values of R and small values of S_y.

The development and selection of each predictive equation generally followed

an interative procedure as outlined below:

Step 1 - Select first order independent variables.

Step 2 - Using variables identified in Step 1, form new independent variables

for the regression analysis consisting of higher order terms and

interreaction (first and higher order) terms. Many computer pro-

grams are available to perform the regression analysis to determine

the significant variables from the total identified and constructed

in Steps 1 and 2.

Step 3 - Examine the residual of plots of the dependent variable vs. regressed

variables. The residual is the difference between what is actually

observed and what is predicted by the regression equation. If the

proper variables were selected, the residual plots will have a

uniform distribution with a zero mean. If the proper variables were

not in the equation, then the residual plots tend to take a shape

which indicates if the analysis should be weighted or a different

term should have been used. An in-depth discussion of the examina-

tion of residuals and their significance is presented in Reference

15.

Step 4 - Repeat Step 2 using new variables and compare R and S_y with pre-

viously established values. Repeat Step 3 (i.e., review of plots

of residuals) and form additional independent variables, if required.

Step 5 - Plot predicted creep responses and compare with experimentally

observed creep curves with particular emphasis placed in identifying

discrepancies in fit and general form of the predicted surfaces.

Step 6 - If major discrepancies are observed in Step 5, modify and/or add

new independent variables and repeat from Step 2.

In general, the regression analyses will be conducted using the natural

logarithm of strain, $\ln\varepsilon$, as the dependent variable. There are two primary

advantages in using logarithmic strain which are: (1) the model tends to come

closer to minimizing the percentage deviations which is desirable, (2) the model

can be forced to satisfy initial boundary value considerations. For example, the

model

$$\ln \varepsilon = A_o + A_1 \ln\sigma + A_2 \ln t$$

when transformed to strain becomes

$$\varepsilon = e^{A_o} \sigma^{A_1} t^{A_2}$$

and if σ or t equal zero, the strain is forced to also equal zero. Boundary con-

ditions for the equations should be carefully investigated to insure applicability

to low stress and time ranges required in the TPS panel analysis.

Another factor to be considered in obtaining empirical creep equations in the

exclusion of high and low strains. By excluding higher strains, a small downward

bias, as shown in Figure 5-3, is introduced in the predictive equations. Likewise,

a small upward bias is introduced into the predictive equation at low strains when

low strains are omitted as is also shown in Figure 5-3.

The justification for removing the low values of creep data is that a

significantly higher percent experimental error exists in the measurement of these

very low creep strains, and that the standard error of estimate can be dominated

by these large observation errors. It should be noted that a weighted least

squares analysis could also be performed which would account for the large variance

in the low strain regime (Reference 15). However, the complexity of such an

approach is greater.
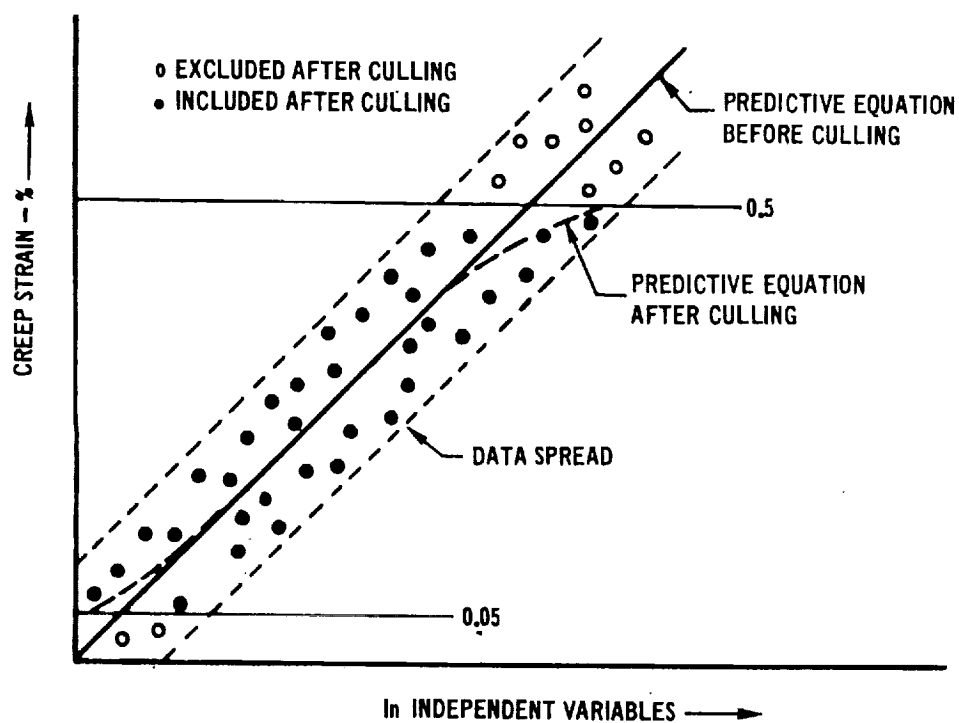
FIGURE 5–3 EFFECT OF CULLING LOW AND HIGH STRAIN DATA ON
PREDICTIVE EQUATION DEVELOPMENT

Creep Accumulation Theories

The applicability of creep accumulation theories appears to be the most significant limitation in the analysis for TPS panel creep deflections. During the Reference 1 studies tests were conducted to provide data for evaluation of the hardening theories. An outline of the test profiles used are shown in Figure 5-4. The objective in these tests is to vary the load as a function of cycle to simulate the increasing or decreasing stress which will occur in a panel due to stress redistribution. Additional tests could also be conducted where temperature would be changed as a function of cycle since both temperature and load level change within a cycle is the analysis due to the varying profiles as well as the stress distribution. Predictions of these tests results can be made using empirical equations developed from constant stress and temperature cycle test data, allowing assessment of the various hardening theories.

Additional Factors Influencing Creep

Assessment of other factors affecting creep may also be important. These factors may include material gage, rolling direction, and possibility of material creep recovery. Evaluation of the effects of atmospheric pressure on creep was also investigated during the Phase I work but was found to have an insignificant effect on the materials investigated. Tensile creep tests can be conducted to assess these effects, if necessary. Steady state tests of specimens at replicate conditions should generally be sufficient to determine any significant variations due to material gage or material rolling direction. No recovery effects were determined for the materials studied based on cyclic tensile testing in Phase I (Reference (1)).

TRAJECTORY PROFILES	LOAD VARIATION WITH CYCLE
a	
b	
c	
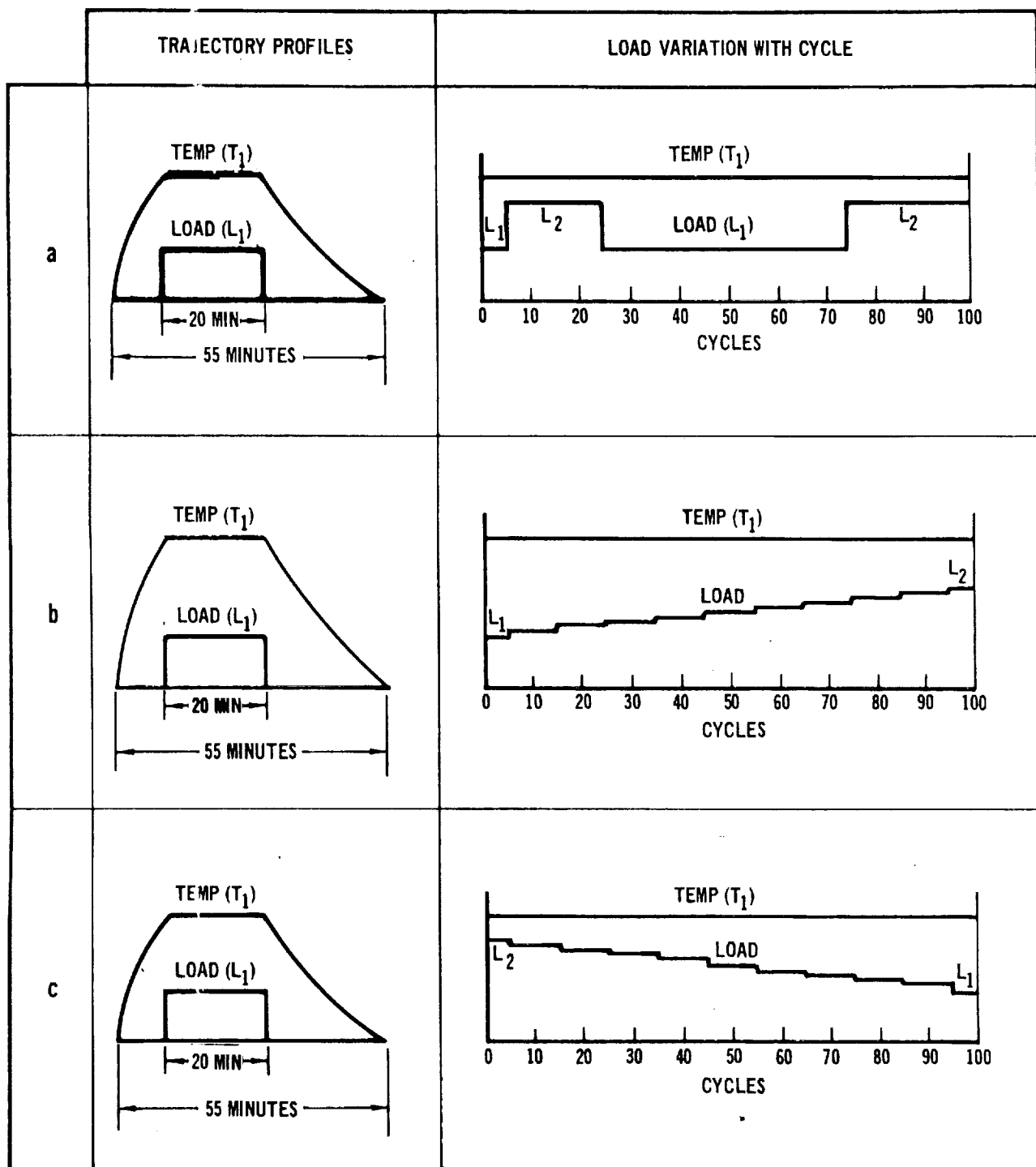
FIGURE 5-4 TESTS FOR EVALUATION OF CREEP ACCUMULATION THEORIES

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

Sensitivity of Creep Strains to Test Accuracy

In conducting tests to assess creep response characteristics of materials, particular attention should be given to maintaining accuracy, since predictions of creep deflections have been demonstrated to be sensitive to variations in temperature and load. Examples of these variations for the empirical equations of L605, Rene' 41, and TDNiCr are presented in Table 5-1 at a time of 20 hours. Based on results of Phase II (Reference 2) and Phase III, prediction accuracy within a factor of 2 should be attainable.

5.4   CREEP DEFLECTION ANALYSIS

Procedures developed for prediction of creep deflections in Thermal Protection System panels are presented in Reference 2 and Appendix B. Included in these references are the approaches and assumptions made in modeling the thin gage panel structures and in performing the analysis to obtain creep deflections. Steps in the analysis are (a) the development of a linear equation describing the logarithm of strain as a function of stress, temperature, and time, (b) idealize the selected loading and temperature profiles into constant steps, and (3) determine deflections using analysis capabilities of the TPSC computer program. Required input in terms of panel temperature distributions, panel geometry definition, and program control parameters are presented in Appendix B. The time hardening theory of creep accumulation has been found to provide the best predictions for subsize panel test results (Reference (2)) and is, therefore, recommended for use in the analysis.

TABLE 5-1. SENSITIVITY OF CREEP STRAINS TO TESTING ACCURACIES

MATERIAL	PARAMETERS IN STRAIN CALCULATION			CREEP STRAIN %	STRAIN VARIATION DUE TO 1% TEMP. CHANGE	STRAIN VARIATION DUE TO 1% STRESS CHANGE
	TEMP.	STRESS	TIME			
L605	1144K (1600°F)	55 MPa (8 KSI)	20 HR.	.615	14.4	3.0
RENE' 41	1089K (1500°F)	138 MPa (20 KSI)	20 HR.	.270	25.8	2.2
TDNiCr	1478K (2200°F)	35 MPa (5 KSI)	20 HR.	.076	5.8	2.0

Selection of "Typical" Profiles

The sensitivity of creep predictions to the temperature profile selection will be illustrated in this section. The curve of creep strain vs. temperature shown in Figure 5-5 is calculated based on the L605 empirical creep equation generated from cyclic tensile tests (Reference Table 2-1). Specific stress and time for the calculated curve are 55 MPa (8.0 ksi) and 20 hours, respectively. The table included in the figure shows resulting creep strains at several temperatures. Also included in the table are the average creep strains over 110K (200°F) temperature increments (i.e. average of strains at T+55K and T-55K) and the percentage errors in creep strain which could result from using the median temperature in each 110K temperature spread. Thus, for example, for a temperature range of 1033K (1400°F) to 1144K (1600PF) the average strain would be .362 which is 35% higher than the value .269 predicted at the median temperature of 1089K (1500°F). This example illustrates the sensitivity of creep strain to temperature and demonstrates that factors such as this should be considered in selecting typical trajectory profiles for analysis. Generally, temperatures higher than the median over the desired range will need to be used in order to arrive at average creep strains and deflections.
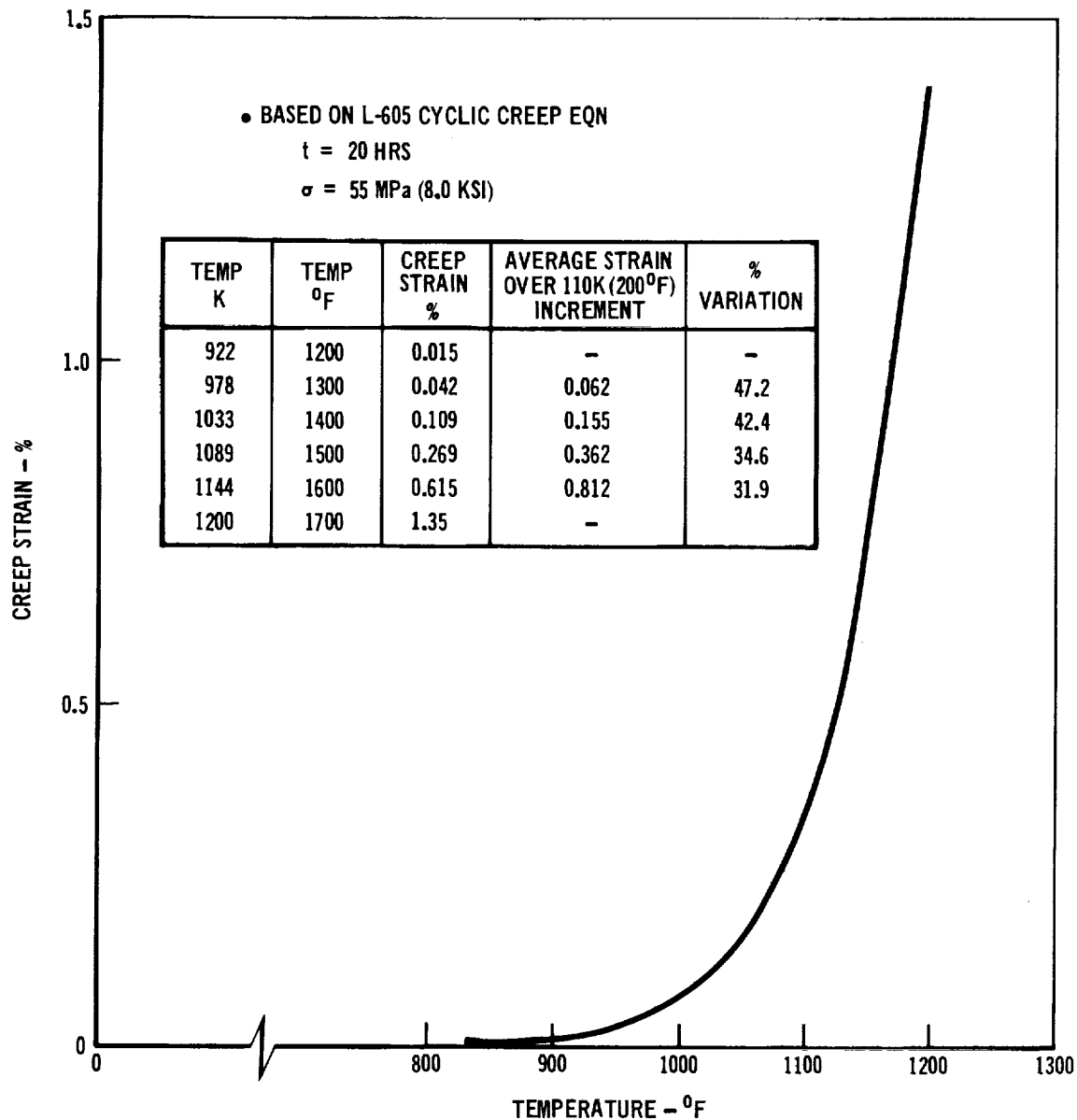
FIGURE 5-5 VARIATION OF CREEP STRAIN WITH TEMPERATURE

Idealization of Load and Temperature Profiles

Some observations related to idealization of load and temperature profiles
into constant steps have been noted during the program. Observations, based on
comparison of tensile test results in Phase I (Reference 1) and subsize panel data
analysis in Phase II (Reference 2) have indicated that a rather simple representa-
tion of four time steps in these studies resulted in successful analysis. It was
shown that a large number of time steps would not improve prediction accuracy. An
example of the steps used is shown in Figure 5-6.
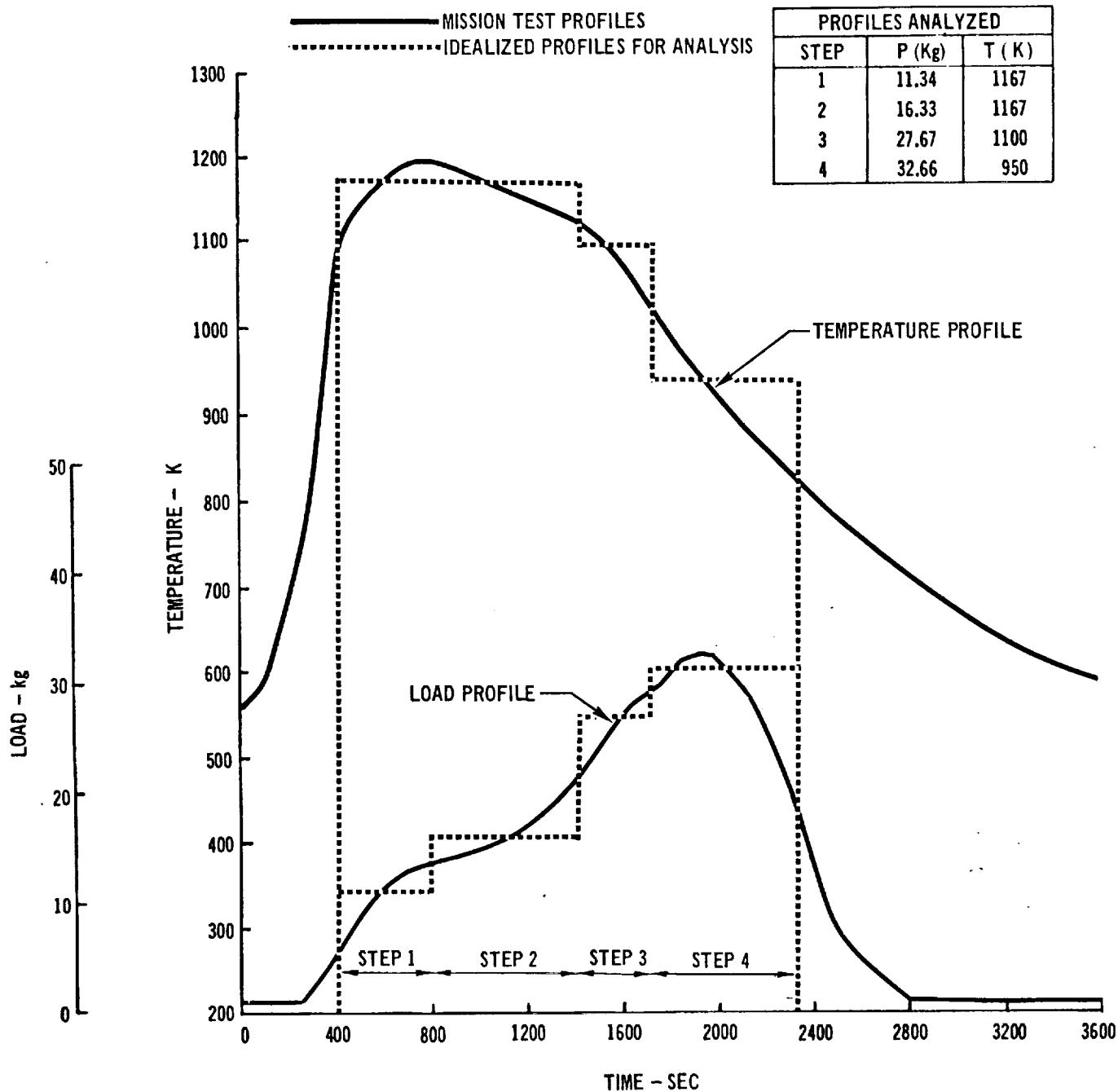
FIGURE 5-6   PROFILE IDEALIZATION FOR ANALYSIS

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APPENDIX A

CONVERSION OF U.S. CUSTOMARY

UNITS TO SI UNITS

CONVERSION OF U.S. CUSTOMARY UNITS TO SI UNITS

The International System of Units (designated SI) was adopted by the Eleventh
General Conference on Weights and Measures in 1960. The units and conversion
factors used in this report are taken from or based on NASA SP-7012, "The Inter-
national System of Units, Physical Constants and Conversion Factors - Revised,
1969".

The following table expresses the definitions of miscellaneous units of
measure as exact numerical multiples of coherent SI units, and provides multiplying
factors for converting numbers and miscellaneous units to corresponding new numbers
of SI units.

The first two digits of each numerical entry represent a power of 10. An
asterisk follows each number that expresses an exact definition. For example, the
entry "-02 2.54*" expresses the fact that 1 inch = 2.54 x 10^{-2} meter, exactly, by
definition. Most of the definitions are extracted from National Bureau of Standards
documents. Numbers not followed by an asterisk are only approximate representations
of definitions, or are the results of physical measurements.

ALPHABETICAL LISTING

To convert from	to	multiply by
atmosphere (atm)	pascal (Pa)	+05 1.0133*
Fahrenheit (F)	kelvin (K)	$t_k = (5/9) (t_f + 459.67)$
foot (ft)	meter (m)	-01 3.048*
inch (in.)	meter (m)	-02 2.54*
mil	meter (m)	-05 2.54*
millimeter of mercury (mm Hg)	pascal (Pa)	+02 1.333
nautical mile, U.S. (n.mi.)	meter (m)	+03 1.852*
pound force (lb_f)	newton (N)	+00 4.448*
pound mass (lb_m)	kilogram (kg)	-01 4.536*
torr (0°C)	pascal (Pa)	+02 1.333

A-2

APPENDIX A - Continued

<u>PHYSICAL QUANTITY LISTING</u>

Area

To convert from	to	multiply by	
$foot^2$ (ft^2)	$meter^2$ (m^2)	-02	9.290*
$inch^2$ (in^2)	$meter^2$ (m^2)	-04	6.452*
$inch^2$ (in^2)	$cemtimeter^2$ (cm^2)	+00	6.452

Density

pound mass/$foot^3$ (pcf, lb_m/ft^3)	kilogram/$meter^3$ (kg/m^3)	+01	1.602
pound mass/$inch^3$ (lb_m/in^3)	kilogram/$meter^3$ (kg/m^3)	+04	2.768
pound mass/$inch^3$ (lb_m/in^3)	gram/$centimeter^3$ (g/cm^3)	+01	2.768

Force

kilogram force (kg_f)	newton (N)	+00	9.807*
pound force (lb_f)	newton (N)	+00	4.448*

Length

foot (ft)	meter (m)	-01	3.048*
inch (in.)	meter (m)	-02	2.54*
micron	meter (m)	-06	1.00*
mil	meter (m)	-05	2.54*
mile, U.S. nautical (n.mi.)	meter (m)	+03	1.852*

Mass

pound mass (lb_m)	kilogram (kg)	-01	4.536*

Pressure

atmosphere (atm)	pascal (Pa)	+05	1.013*
millimeter of mercury (mm Hg)	pascal (Pa)	+02	1.333
newton/meter	pascal (Pa)	00	1.00*
pound/$foot^2$ (psf, lb_f/ft^2)	pascal (Pa)	+01	4.788
pound/$inch^2$ (psi, lb_f/in^2)	pascal (Pa)	+03	6.895

Temperature

Fahrenheit (F)	Kelvin (K)	$t_k = (5/9)(t_f + 459.67)$

APPENDIX A - Continued

Volume

To convert from	to	multiply by	
foot^3 (ft^3)	meter^3 (m^3)	-02	2.832*
inch^3 (in^3)	meter^3 (m^3)	-05	1.639*
inch^3 (in^3)	centimeter^3 (cm^3, cc)	-01	1.639

PREFIXES

The names of multiples and submultiples of SI units may be formed by application of

the prefixes:

Multiple	Prefix
10^{-6}	micro (μ)
10^{-3}	milli (m)
10^{-2}	centi (c)
10^{-1}	deci (d)
10^3	kilo (k)
10^6	mega (M)
10^9	giga (G)

APPENDIX B

USERS INFORMATION

THERMAL PROTECTION SYSTEM CREEP

(TPSC)

COMPUTER PROGRAM

B.1 INTRODUCTION

The computer program described herein, Thermal Protection System Creep (TPSC), uses iterative techniques and numerical integration to predict creep strains, residual stresses, and permanent deflections in stiffened panel structures. This program was developed jointly under internal MDAC funding and NASA Langley Research Center contractual funding. Initiated at MDAC in 1971, the program has been continually modified to increase its capability. Although the TPSC Computer Program was developed for analysis of creep deflections in thermal protection system panels, it is applicable to creep analysis in any beam or stiffened plate structure subjected to bending loads. The TPSC program is written in CDC Fortran IV and is operational on the MCAUTO/CDC 6000 series computers using KRONOS operating systems.

A flexible, user oriented input format is used. Input data include panel geometry and definition of loading and temperature profiles. Panel temperature distributions along the panel length and through the depth can be input using either polynomial equation coefficients or tabular input. Temperatures at each location in the panel are based on these distributions and the input temperature-time profile data. Also, input are equation coefficients to define material creep response as a function of time, stress, and temperature.

Program output includes a record of input data and calculated geometrical data (elastic moment of inertia), trajectory load and temperature data, and creep equation definition as well as the calculated deflections, creep strains, and residual stresses.

The program was developed specifically for analysis of thermal protection system panels. Therefore, definition of leading structural concepts, corrugation

stiffened, rib stiffened, and zee stiffened concepts, is incorporated into the

TPSC program. Modeling of the specific panel structural concept for analysis is

accomplished automatically based on overall section input definition. Appropriate

use of input parameters also allows analysis of rectangular and I-beam sections.

An option is provided for including a beaded skin into any of the cross sections

since beads are frequently required in thermal protection system panel designs.

Bending moments are internally defined based on uniform pressure load input

or two point load input. In addition, the moments can be calculated as a function

of panel edge support stiffness and the ratio of panel stiffness in the longitudinal

and transverse directions. This option is based on combining solutions for an

isotropic plate with two sides simply supported and two sides elastically supported

as offered by Timoshenko (Reference 4) and the solution for an orthotropic plate

with four sides simply supported as offered by Lekhnitskii (Reference 5). This

option provides a first order approach to account for Poisson's effects in

orthotropic plate structures.

Sensitivity of predicted results to the number of elements defining panel

cross section and the number of stations defining panel length has been investigated

with the goal of providing guidelines for minimizing required computer time.

Computer time increases almost linearly with number of analysis steps specified.

The minimum number of stations along the length and elements through the depth which

can be used to maintain good prediction accuracy have been defined.

The TPSC computer program provides needed capability for prediction of perma-

nent deflections, due to creep, in entry vehicle metallic thermal protection

system panels. Application is also envisioned in other structures where creep

deflections may be important such as in missile structures and nuclear reactors.

B.2 METHOD OF ANALYSIS

Within the TPSC program the panel length is divided into i stations over which bending moments are assumed constant and the panel depth is divided into j elements over which stresses are assumed constant as indicated in Figure B-1.

Using the assumption of a linear total elastic plus creep strain distribution through the depth, the neutral axis and structural rotation are systematically varied at each station and time step to determine the unique stress distribution which satisfies both force and moment balance requirements. At each point in the panel the creep component of total strain is determined based on either the time hardening or strain hardening theory of creep accumulation applied in conjunction with input analytical expressions defining material tensile creep response as a function of stress, temperature, and time. Residual stresses are calculated at each time step by subtracting the elastic stress from the total calculated stress. These residual stresses are used at initiation of analysis for the next time step. Analysis proceeds through all the time steps at each designated station along the panel length, accumulating and storing structural rotations, creep strains, and residual stresses. At the completion of analysis, rotations are numerically integrated to determine creep deflections.

The following assumptions are made in the analysis:

(a) Only bending stresses are considered in the analysis. Deflections due to shear are assumed negligible.
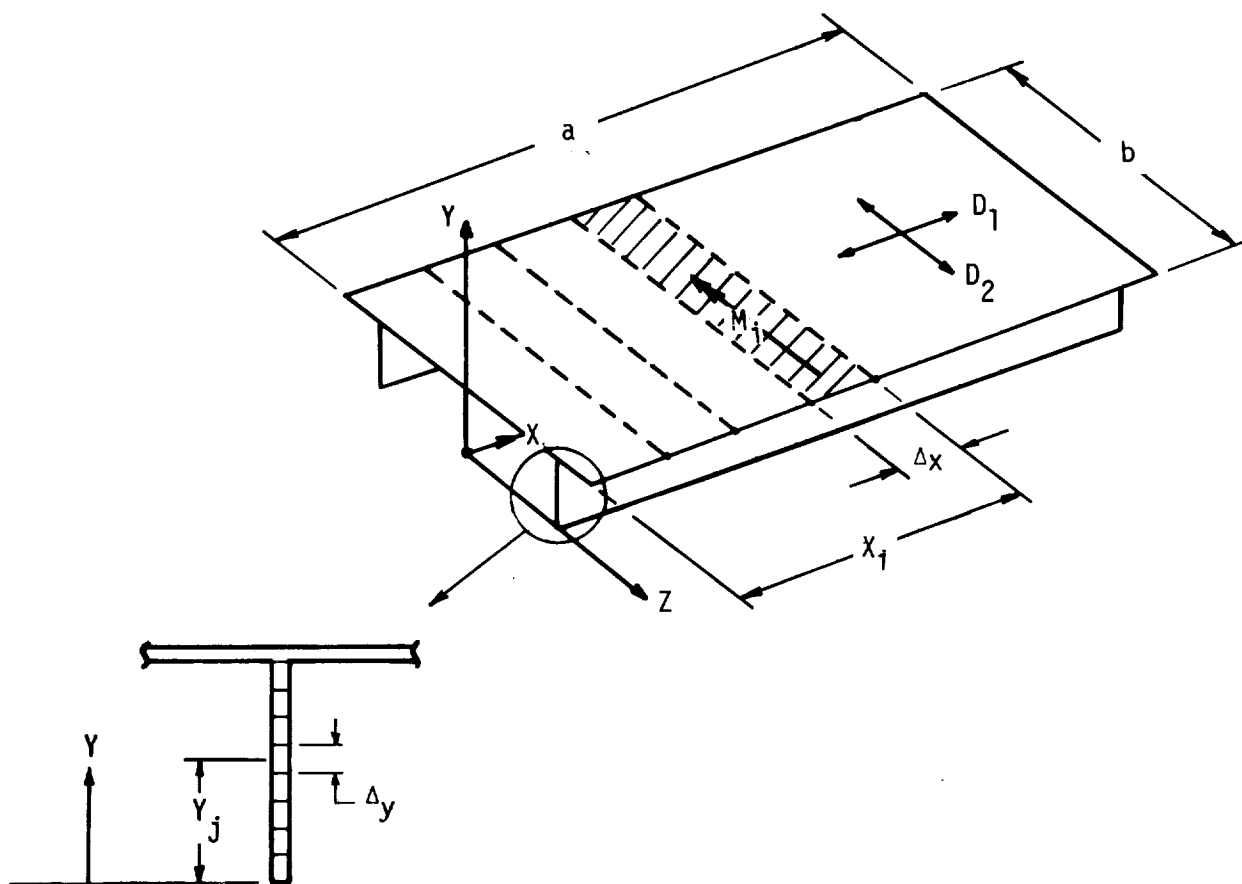
FIGURE B-1.   PANEL REPRESENTATION FOR ANALYSIS

(b) Strain distributions through the panel depth are linear.

(c) Creep response equations, defined by the user, are assumed to be applicable for both tensile and compressive stresses.

(d) Load and temperature distributions and calculated deflections are assumed symmetrical with respect to the panel centerline $(X = a/2)$.

(e) Panels are thin gage. (Although the analysis is not restricted to thin gages, the approach for modeling specific section geometries incorporated into the program has been based on this assumption.)

Approaches used for important program calculations are presented in this section. The general analysis flow is shown in Figure B-2 for reference purposes.

B.2.1 Geometry Definition

Analysis capability for three thermal protection system structural concepts; rib stiffened (INDGEO = 1), corrugation stiffened (INDGEO = 2), and zee stiffened (INDGEO = 3), is incorporated into the TPSC program. The number of stiffeners across the panel width are defined by NRIB, NCOR, and NZEE for the rib, corrugation, and zee stiffened concepts, respectively. A skin bead in either the positive y or negative y direction can be included in the cross sections at the user's option (INDBD = 1). The direction of the skin bead is specified by the sign of the input bead radius (BRAD) where a + sign designates the bead in the + y direction from the skin. Geometry of the TPS cross sections and skin bead, defining program input variables, are shown in Figure B-3.

The approach for modeling the rib stiffened, corrugation stiffened, and zee stiffened subsize TPS panels is shown in Figure B-4. The number of stations in half the panel length are defined by input variable NSTAT. This is defaulted to 6 when not input by the user. The number of elements through the panel depth is defined by input variables NSECT and SEC. These are both defaulted to 10
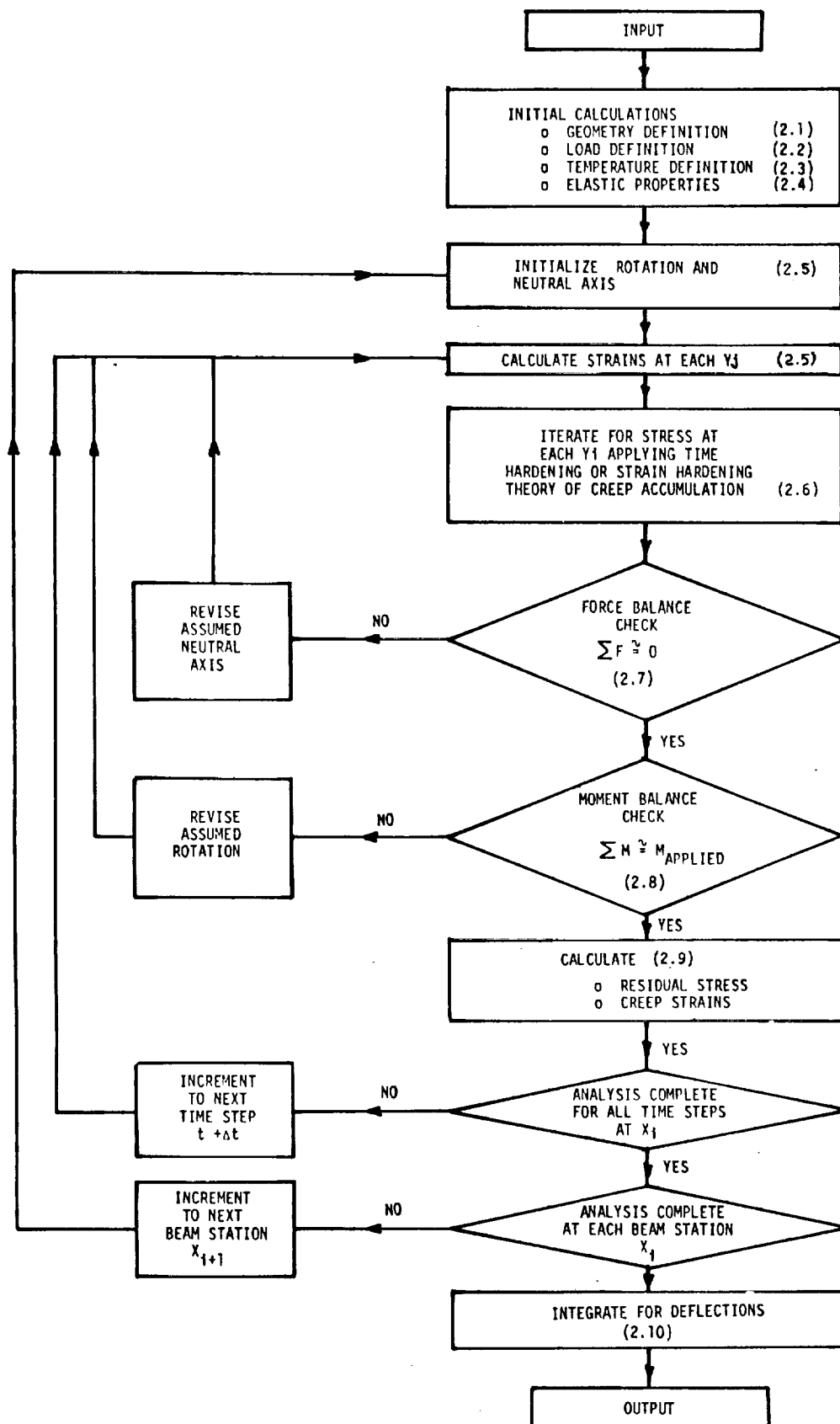
FIGURE B-2 TPSC PROGRAM ANALYSIS FLOW
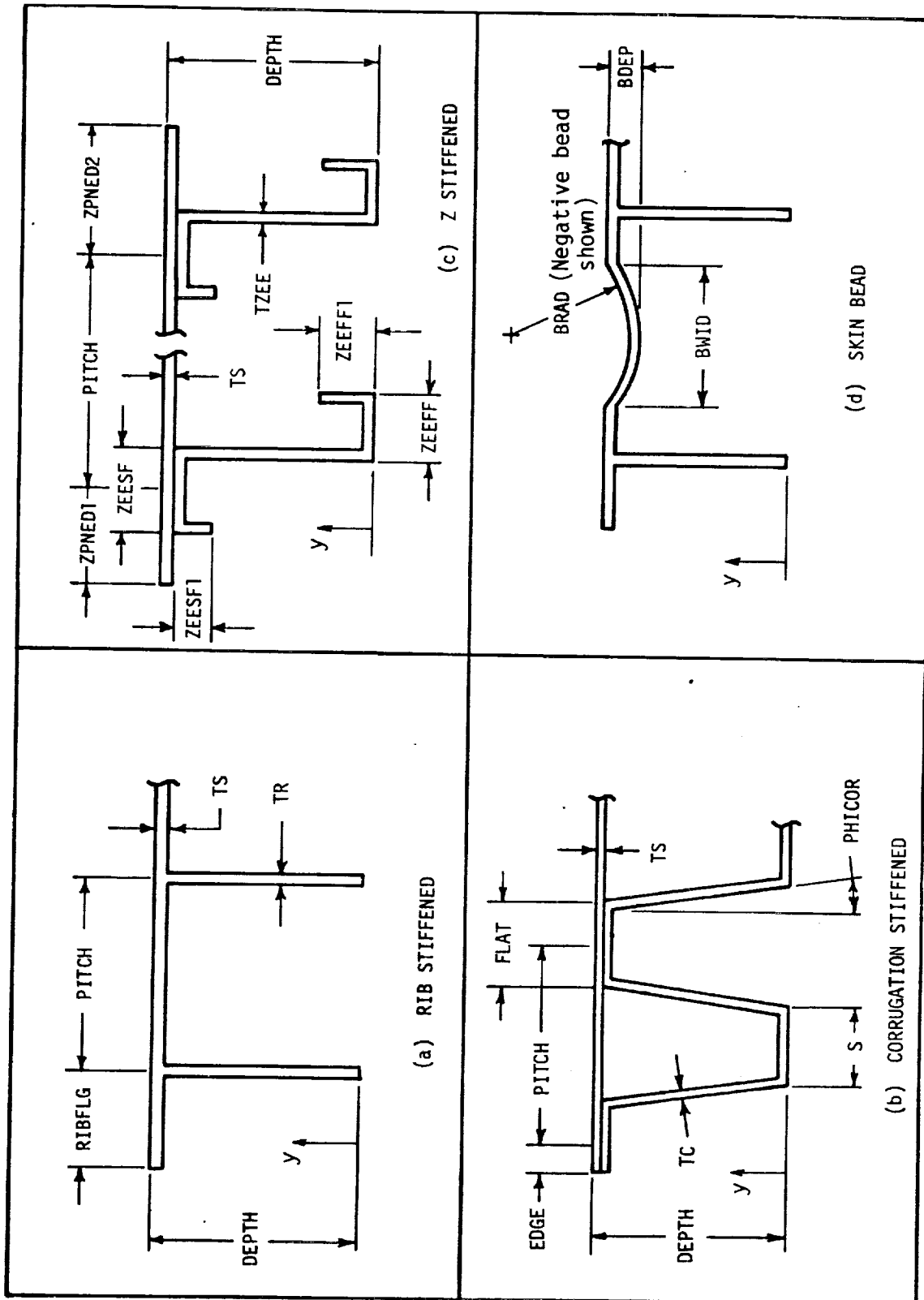
Figure B-3 PANEL GEOMETRY DEFINITION

(a) RIB STIFFENED

(b) CORRUGATION STIFFENED

(c) Z STIFFENED

(d) SKIN BEAD

SINGLE SKIN CORRUGATION PANEL SECTION

RIB PANEL SECTION

Z PANEL SECTION

BEAD SECTION
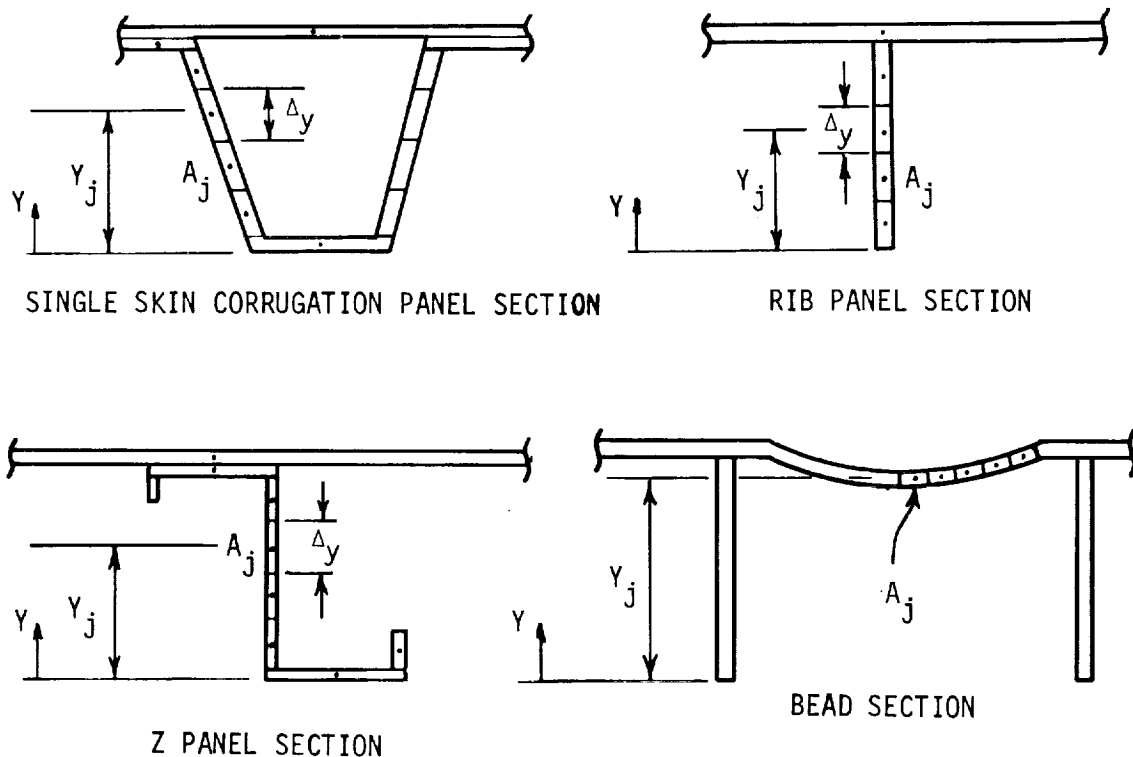
FIGURE B-4 STRUCTURAL MODELING OF PANEL AND CROSS SECTIONS

when not input by the user. Two variables (fixed point (integer) and floating

point (real)) are used in order to make the program as machine independent as

possible. The assumption of thin gages allows skin and horizontal stiffener

sections (e.g., skin) to be defined as individual elements. Vertical portions of

the stiffeners (e.g., ribs) are divided into ΔY elements based on the input total

number of elements (NSECT, SEC) minus the number of horizontal elements. There-

fore, for example, the calculation for ΔY for the corrugation concept is $\Delta Y =$

[DEPTH-TS-2(TC)]/(NSECT-3). For beaded skins five additional elements are added

into the cross section as shown in Figure B-4. Centroids and areas of the cross

section increments are used in all subsequent program calculations.

B.2.2 Load Definition

Panel bending loads are calculated based on input pressure (PRESS) or point

loads (PLOAD) for each time step in the mission profile. These are selected by

inputting INDLOD=0 for pressure load and INDLOD=1 for point loads. Calculations of

beam bending moments under the pressure and point load options are shown in Figure

B-5. Input XLGTH and PANWID values correspond to a and b respectively. All applied

loads are assumed symmetrical about the panel centerline. Units for PLOAD are Lbs

or Kg where the input value is the total panel load. Input pressure units are

Pa/cm^2 or Lbs/in^2. The panel width is included in the pressure loading calculations

to yield the total panel bending moment at each beam station. The option for apply-

ing point loads to the panel, was specifically included to allow analysis of subsize

panel test data (Reference 2). For this type of loading the distance (ALEN) from

the support to the point of load application is input. Analysis for a single midspan

point load can be implemented by making ALEN equal to one half of the panel length.

For panels loaded with a uniform pressure, an option is included for modifying

the bending distribution (INDPLA=1) to account for plate effects. The plate option

provides a first order approach to account for Poisson's effects and edge stiffness

B-10

(a) PRESSURE LOADS (SIMPLE SUPPORTS)
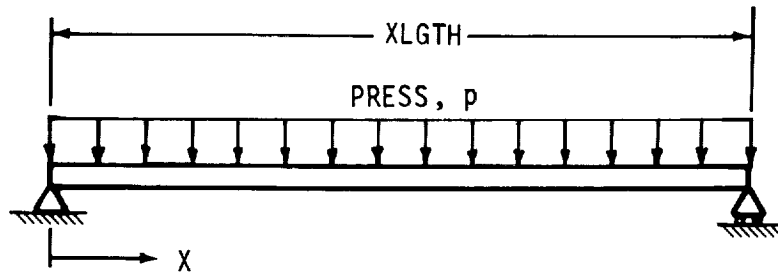
$$M = \frac{PRESS}{2} \ (XLGTH(X) - X^2) \ (PANWID)$$

(b) TWO POINT LOADING (SIMPLE SUPPORT)
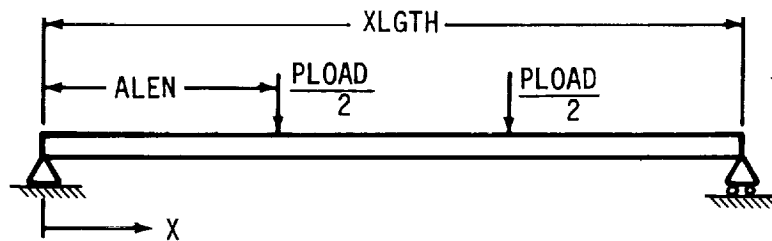
$$M_{o-ALEN} = \frac{PLOAD}{2} \ X$$

$$M_{ALEN-XLGTH/2} = \frac{PLOAD}{2} \ (ALEN)$$

Figure B-5. LOAD OPTIONS

B-11

effects in orthotropic plate structures by combining solutions for an isotropic plate

with two sides simply supported and two sides elastically supported as offered by

Timoshenko (Reference 4) and the solution for an orthotropic plate with four sides

simply supported as offered by Lekhnitskii (Reference 5). This option is restricted

to panels where $b \geqslant a$ and $D_1 \geqslant D_2$ (Figure B-1). The value D_1 is calculated in the pro-

gram. Stiffness in the transverse direction (D_2) can be input (using the variable

DETWO) or calculated, based on skin thickness as $(TS)^3/12(1-\nu)^2$. The parameter λ

defining the relative stiffness of the edge support and the panel is calculated as

$\lambda = ESTIFF/aD_1$ where ESTIFF is the input support stiffness along the edges $Z = \pm b/2$.

Panel midspan ($Z=0$, $X = a/2$) bending moments for typical b/a values are shown

in Figure B-5(a) and B-5(b) as functions of the quantities λ and D_1/D_2 respectively.

These solutions are combined in the analysis by assuming that the variation of

moment as a function of λ, will be applicable at all D_1/D_2 values. This assumption

is felt to be justified because it is exactly applicable at $D_1/D_2 = 1$ (isotropic

panel) and any variations at other D_1/D_2 will be a small portion of the total moment

since values are constrained in a narrow range (Figure B-5(b)).

In computing the midspan moment M, the moment M_L for the orthotropic plate with

four sides simply supported (Figure B-6(b)) is first calculated. This moment is

then increased based on the degree of edge support using the calculated moment M_T

for an isotropic plate (Figure B-6(a)). The solution for M (Figure B-6(b)) is then

calculated based on the relationship that the increase in moment ($M-M_L$) toward

$.125$ pa^2 will be proportional to the increase ($M_T - M_{T_{\lambda=\infty}}$) due to panel edge

stiffness.

This results in the equation

$$\frac{M - M_L}{.1250 - M_L} = \frac{M_T - M_{T_{\lambda=\infty}}}{M_{T_{\lambda=0}} - M_{T_{\lambda=\infty}}}$$
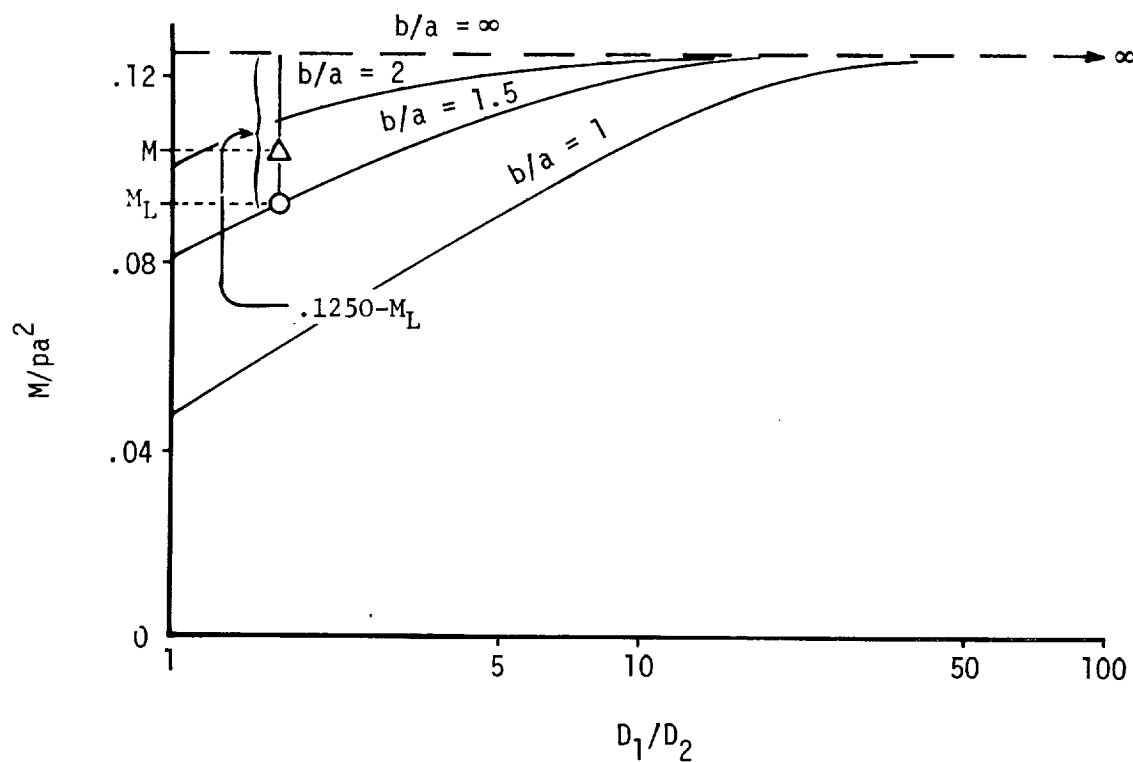
(b) LEKHNITSKII SOLUTION - MIDSPAN MOMENT
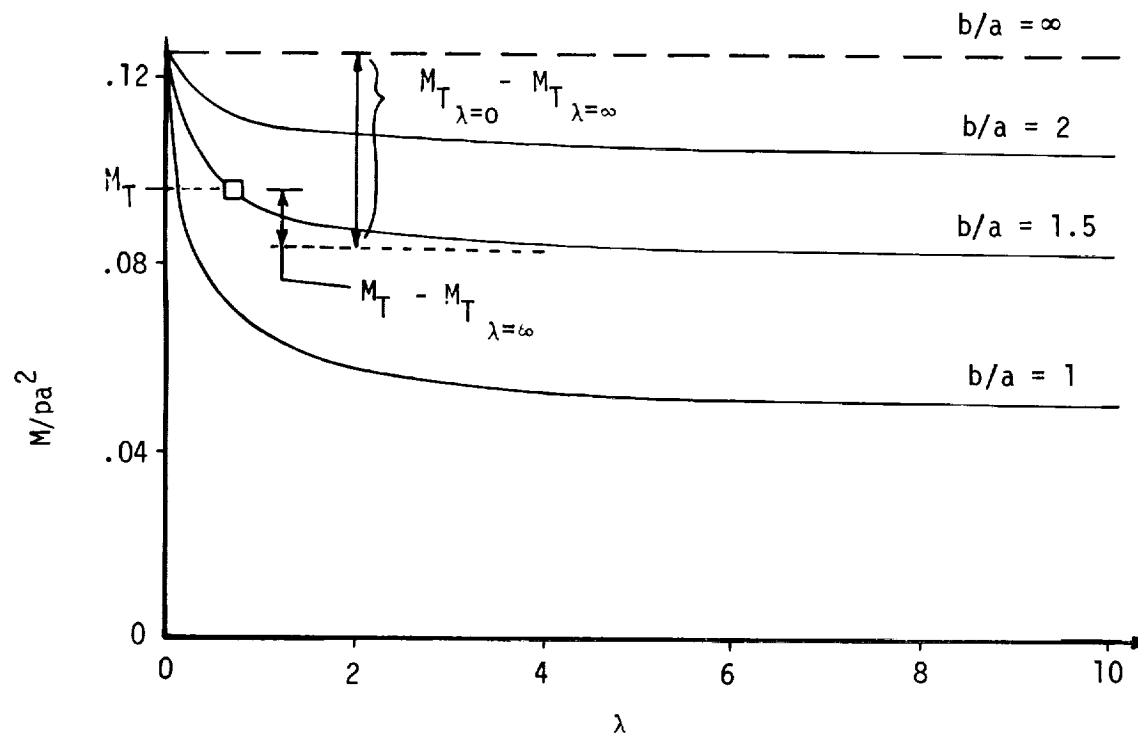
(a) TIMOSHENKO SOLUTION - MIDSPAN MOMENT

FIGURE B-6   PLATE BENDING MOMENT SOLUTIONS

B-13

which yields

$$M = M_L + (.1250 - M_L) \frac{M_T - M_{T_{\lambda=\infty}}}{M_{T_{\lambda=0}} - M_{T_{\lambda=\infty}}} \qquad (B-1)$$

Moments along the panel length are calculated based on ratioing the beam bending
moment distribution (Figure B-5(a)), using the equation B-1 value at midspan.

B.2.3 Temperature Definition

Panel temperature distributions are defined by input of the panel midspan
skin temperatures at each mission time step, the distribution of temperature through
the panel depth, and the distribution of temperature along the length. Normalized
temperature distributions, referenced to the midspan skin temperature, are input,
as indicated in Figure B-7(a). The midspan skin temperature (TEMP) is input for
each trajectory time step (DXTIME) up to the number of steps (NTIME). Distributions
through the panel depth and along the length are defined by either of the following
approaches.

(1) A table lookup routine is included in the program to calculate T_x and
T_y as functions of X and Y, respectively, based on tabular input. The distribution
along the panel length (INDTFL = 1) and through the panel depth (INDTFD = 1) are
input using the variables XTEMP and YTEMP, respectively. Temperatures (normalized
to 1.0 at the midspan skin) are input to define these distributions as shown in
Figure B-7(b). The distribution T_y is assumed to be the same at each location
along the panel length. Temperature is calculated, at each point in the
panel, as the product of TEMP (function of time), T_x (function of length), and T_y
(function of depth). T_x and T_y are determined using linear interpolation between
input points as shown in the figure.

(2) Temperature can be defined by the input of coefficients (C and D) to the
following polynomial equations.

B-14
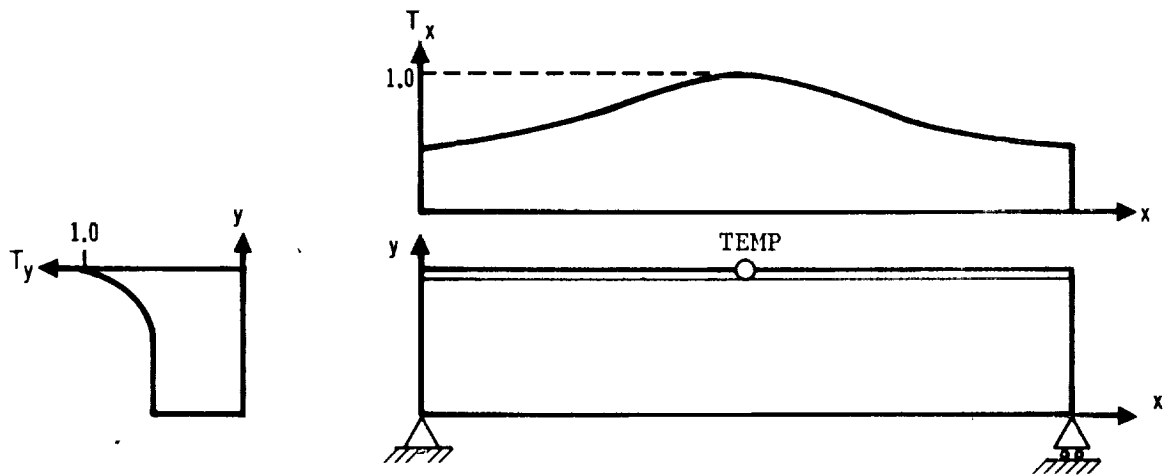
$$T = TEMP \ (T_x) \ (T_y)$$

(a) Temperature Defined as Function of Panel Length and Depth
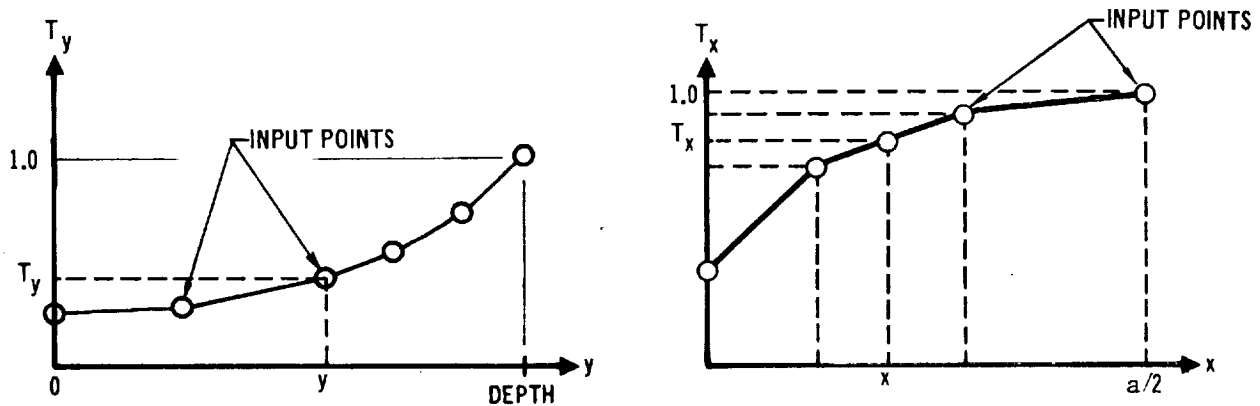
(b) Linear Interpolation for Temperatures
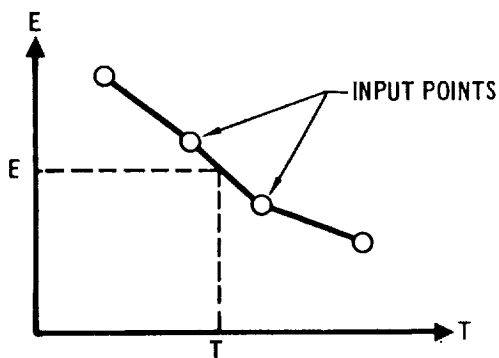
(c) Linear Interpolation for Elastic Modulus

FIGURE B-7 PANEL TEMPERATURE CALCULATIONS

B–15

$$T_X = C_1 + C_2 X + C_3 X^2 + C_4 X^3 \qquad\qquad\qquad (B-2)$$

$$T_Y = D_1 + D_2 Y + D_3 Y^2 + D_4 Y^3 \qquad\qquad\qquad (B-3)$$

For this option the control variables INDTFL and INDTFD are defaulted to 0.

For temperatures defined by either of these options the control variable ITCON must be set equal to 0.

Elastic modulus data, for use in the analysis, are defined as a function of temperature by either of the same two approaches described for defining temperature distributions.

(1) For using the table lookup routine, modulus and temperature data are input in tabular form using the input variable ETEMP, as shown in Figure 2-7(c). For this option the control variable INDMOD is input as 1.

(2) The modulus can also be defined by equation coefficients (ECOEFF) to the equation:

$$E = ECOEFF_1 + ECOEFF_2 (T) + ECOEFF_3 (T^2) + ECOEFF_4 (T^3) \qquad (B-4)$$

B.2.4 Elastic Calculations

Elastic stresses (σ_e), strains (ε_e), and rotations (θ_e) at each station as well as the section neutral axis ($\overline{Y}_e$) and moment of Inertia (I) are calculated as follows, where the subscript j represents element location in the cross section (Figure B-4)

$$\overline{Y}_e = \frac{\displaystyle\sum_{j=1}^{NSECT} A_j Y_j}{\displaystyle\sum_{j=1}^{NSECT} A_j} \qquad\qquad (B-5)$$

B-16

$$I = \sum_{j=1}^{NSECT} A_j Y_j^2 - \overline{Y}^2 \sum_{j=1}^{NSECT} A_j \qquad \text{(B-6)}$$

$$\sigma_{e_j} = \frac{M_i (\overline{Y}_e - Y_j)}{I} \qquad \text{(B-7)}$$

$$\varepsilon_{e_j} = \sigma_{e_j}/E \qquad (E = \text{elastic modulus}) \qquad \text{(B-8)}$$

$$\theta_{e_i} = \frac{M_i \, \Delta X}{E \quad I} \qquad \text{(B-9)}$$

In the moment of inertia calculation, the moments of inertia of individual j elements, about their own neutral axes, have been found to be negligible and have not been included.

B.2.5 Iteration for Stress

At each beam station (X_i) the incremental rotation due to creep (θ_c) and neutral axis $(\overline{Y})$ are initialized as

$$\theta_c = \theta_e \qquad \text{(B-10)}$$

$$\overline{Y} = \overline{Y}_e$$

Based on these values, the initial total strain assumed at each Y element (Y_j) is calculated, using the linear total strain assumption

$$\varepsilon_{T_j} = (\theta_c + \theta_e) \, (\overline{Y} - Y_j)/\Delta X \qquad \text{(B-11)}$$

For each j element through the cross section there is a unqiue value

of stress (σ_j) which satisfies the equation:

$$\varepsilon_{T_j} = \varepsilon_{c_j} + \frac{\sigma_j + \sigma_{RESIDUAL_j}}{E} \tag{B-12}$$

where $\sigma_{RESIDUAL_j}$ is the residual stress based on results from calculations in the

previous time step (zero for the first step) and E is the material elastic modulus

at the element temperature.

The incremental creep (ε_{c_j}) is a function of stress, temperature, time,

and incremental time step based on the input creep strain equation (Section B.3.7)

applied in conjunction with the hardening theories. Calculations of ε_{c_j} as a

function of stress, strain, temperature, and time for the strain hardening and

time hardening creep accumulation theories are discussed in Section B.2.6.

In determining the value of stress at each element which satisfies Equation

B-12, assumed stresses (designated by the subscript ℓ) are systematically varied

and corresponding strains (ε_ℓ) are calculated. The subscript ℓ has been added in

this section to designate stresses and strains calculated in the iteration process.

The subscript j is applied to the final stresses determined at each element. The

initially assumed value of stress σ_ℓ ($\ell = 1$) is that obtained from analysis in the

previous time step (elastic stress for the first time step). The assumption for

the second value of σ_ℓ ($\ell = 2$) is dependent on the value of σ_1 and the relationship

between ε_{T_j} and the calculated strains ε_ℓ (ε_1 for $\ell = 1$) as follows:

(a) $\sigma_2 = -100.$ psi. for $(\sigma_1 = 0.$ and $\varepsilon_{T_j} < \varepsilon_1)$

(b) $\sigma_2 = +100.$ psi. for $(\sigma_1 = 0.$ and $\varepsilon_{T_j} > \varepsilon_1)$

(c) $\sigma_2 = 2 (\sigma_1)$ for $(\sigma_1 < 0.$ and $\varepsilon_1 > 0.$ and $\varepsilon_{T_j} < \varepsilon_1)$

or

$(\sigma_1 > 0.$ and $\varepsilon_1 > 0.$ and $\varepsilon_{T_j} > \varepsilon_1)$

(d) $\sigma_2 = \sigma_1 + |\sigma_1|$ for $\dfrac{\varepsilon_1}{\varepsilon_{T_j}} < .1$ and $\varepsilon_{T_j} > 0$ (B-13)

(e) $\sigma_2 = \sigma_1 - |\sigma_1|$ for $\dfrac{\varepsilon_1}{\varepsilon_{T_j}} < .1$ and $\varepsilon_{T_j} < 0$

(f) $\sigma_2 = \sigma_1 \dfrac{\varepsilon_{T_j}}{\varepsilon_1}$ for $\dfrac{\varepsilon_1}{\varepsilon_{T_j}} > .1$

Subsequent values of σ_ℓ are calculated by applying the equation

$$\sigma_\ell = \sigma_{\ell-1} + (\varepsilon_{T_j} - \varepsilon_{\ell-1}) \text{ SLOPE} \qquad (B-14)$$

where SLOPE $= (\sigma_{\ell-1} - \sigma_{\ell-2})/(\varepsilon_{\ell-1} - \varepsilon_{\ell-2})$

The process which is representative in Figure B-8 is continued until the stress is
determined such that

$$\frac{\varepsilon_{T_j}}{\varepsilon_\ell} - 1. < .001$$

An analysis proceeds through each time step the neutral axis and rotation are
initialized as equal to those calculated in the previous time step.
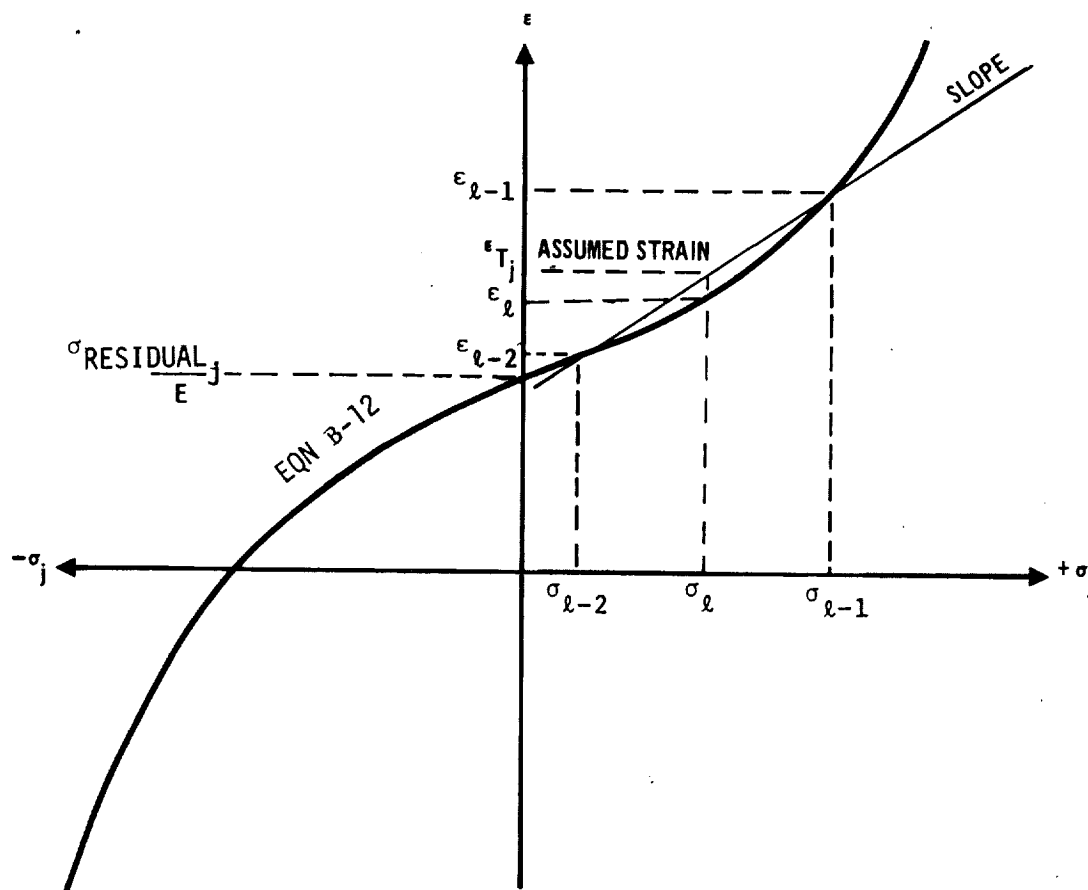
FIGURE B -8 ITERATION APPROACH FOR STRESS CALCULATION

B.2.6 Hardening Theories

The time hardening and strain hardening theories of creep accumulation are provided in the TPSC program. These are selected through input of the control variable HARDOP = 1 and HARDOP = 2 respectively.

The time hardening theory of creep accumulation is based on the assumption that the creep rate is dependent upon the total time under load. This approach for calculation of incremental creep strains is shown in Figure B-9(a). Stresses are iteratively determined at each time step based on input creep strain equations.

The strain hardening theory of creep accumulation is based on the assumption that the creep rate is dependent upon total accumulated creep strain. This approach for calculation of incremental creep strains is shown in Figure B-9(b). Additional calculations are required under this option to determine the effective time, for which the given value of strain applies, at a new stress and/or temperature. Therefore, this option requires more computer time (Reference Section B.6). To facilitate analysis of mission profiles, a maximum time cutoff (TMAX) is input to prevent application of the creep equation beyond its range of applicability. For times beyond this time cutoff, the equation creep rate is assumed constant for each stress and temperature as indicated in the figure.

B.2.7 Force Balance Requirements

Having solved for stresses at each of the j element locations, the check for a zero force balance on the cross section is calculated as

$$F = \sum_{j=1}^{NSECT} \sigma_j A_j \qquad \text{(B-15)}$$

Based on the resulting sign (plus or minus) of F the neutral axis location is changed by $\mp \Delta Y$. That is, for example, if the neutral axis is located toward the tension side of the panel, resulting in an overall net compresssion load (F = negative), then the neutral axis must be moved toward the compression side (+Y direction). Strains and stresses are then recalculated. This process is continued until the sign of F changes, at which time the neutral axis location is calculated by linear interpolation using the equation

$$\overline{Y} = \overline{Y}_m - \frac{|F_m| \; (\overline{Y}_m - \overline{Y}_{m-1})}{|F_m| + |F_{m-1}|} \qquad \text{(B-16)}$$

where m is a subscript used to designate the final two axis locations and associated force summations in calculating $\overline{Y}$. This process is indicated in Figure B-10. It should be noted that the neutral axis location is not constrained to coincide with the Y_j element centroids.

PREDICTION OF CREEP IN
METALLIC TPS PANELS   PHASE III
SUMMARY REPORT   NAS-1-11774
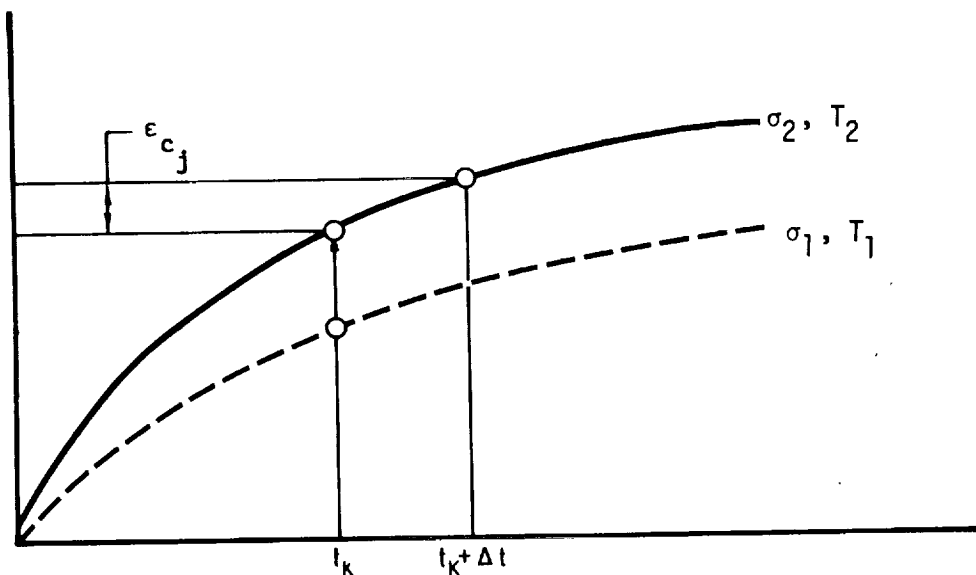
(a) Time Hardening
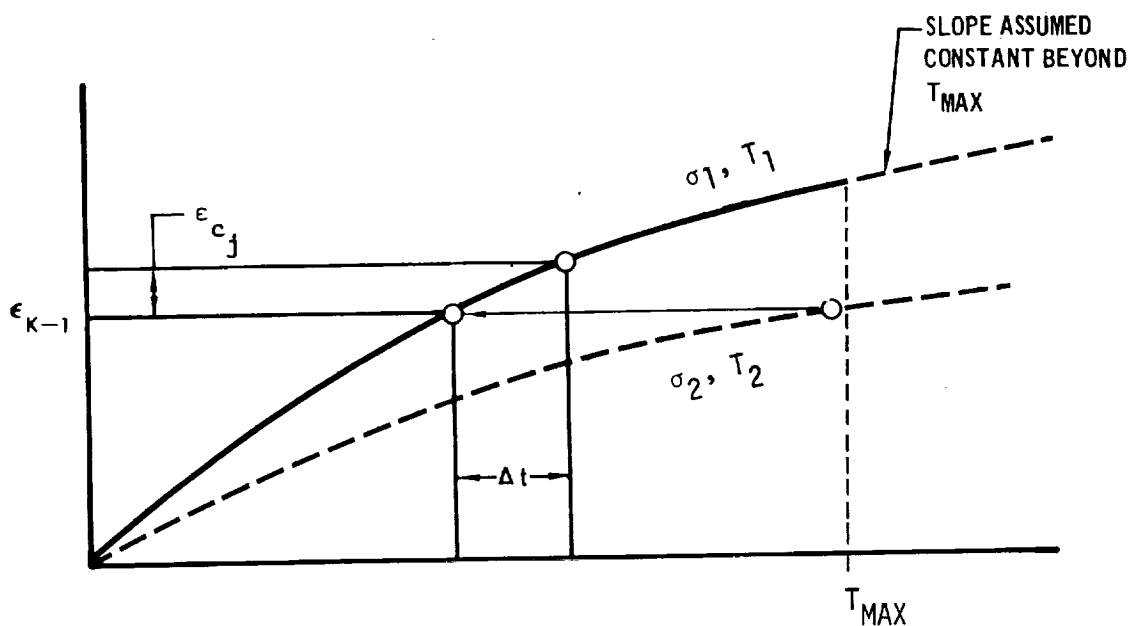
(b) Strain Hardening

FIGURE B-9   HARDENING THEORIES FOR CREEP ACCUMULATION.

$$\sum F_{m-1} = -$$

$$\sum F_m = +$$
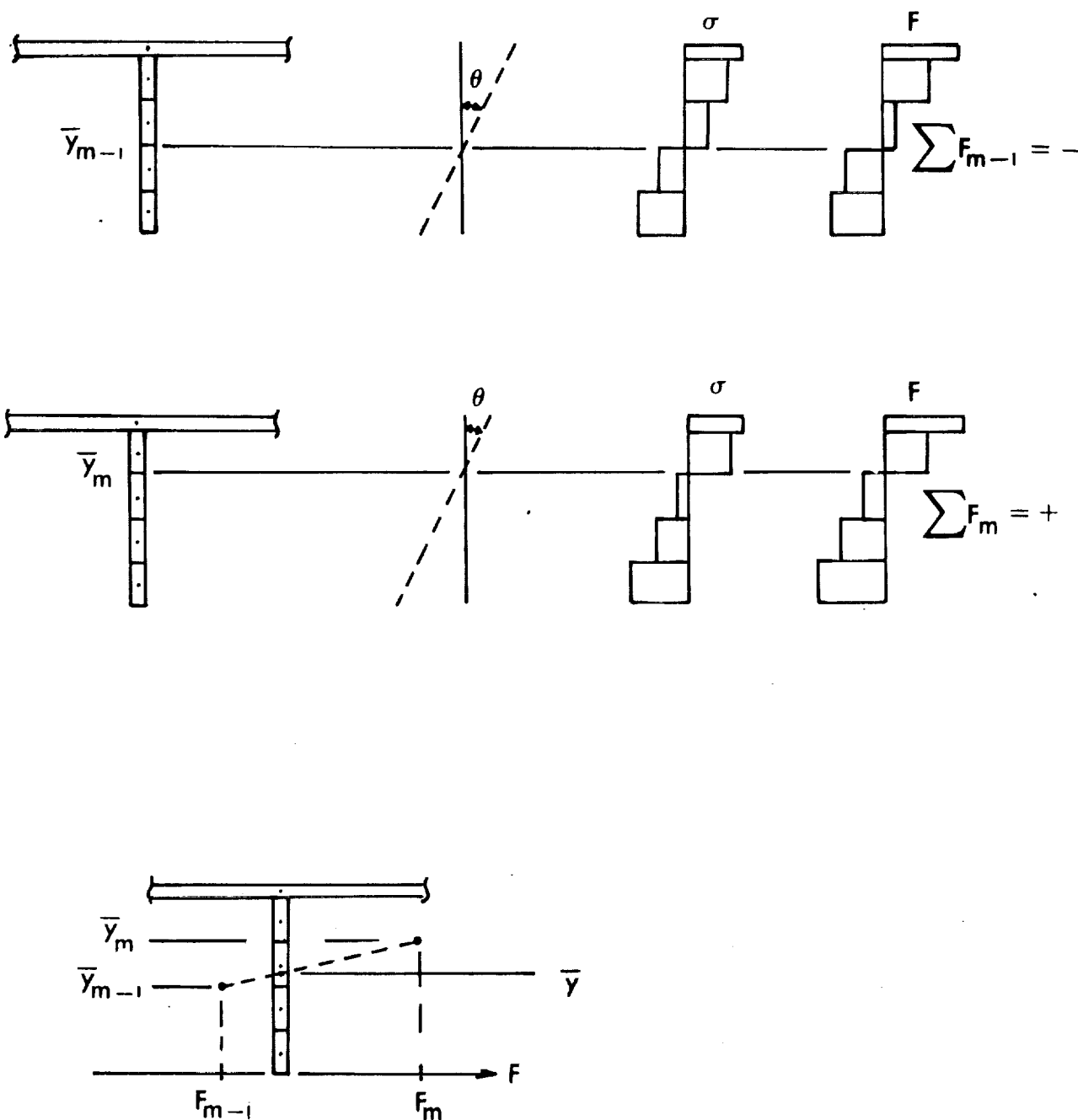
FIGURE B-10   FORCE BALANCE ITERATION APPROACH

B.2.8 Moment Balance Requirements

After force balance is attained at the cross section the check for moment balance at the station is calculated as

$$M_1 = \sum_{j=1}^{NSECT} \left| \sigma_j \, A_j \, (\bar{Y} - Y_j) \right|$$ (B-17)

The second estimate of θ is

$$\theta_2 = \theta_1 \left(\frac{M_{applied}}{M_1} \right)$$ (B-18)

Subsequent assumed rotations are calculated based on the equation

$$\theta_n = \theta_{n-1} + (M_{applied} - M_{n-1}) \, \frac{(\theta_{n-1} - \theta_{n-2})}{(M_{n-1} - M_{n-2})}$$ (B-19)

as depicted in Figure B-11 where n is a subscript used to designate the assumed rotations and associated moments calculated. Each M_n is compared to $M_{applied}$. Balance is established when

$$\frac{\left| M_n - M_{applied} \right|}{M_{applied}} < .001$$

The value of .001 for moment balance covergence was established to provide good solution accuracy within reasonable computer run times.

B-25

$M_{n-2} < M_{applied}$

$M_{n-1} > M_{applied}$
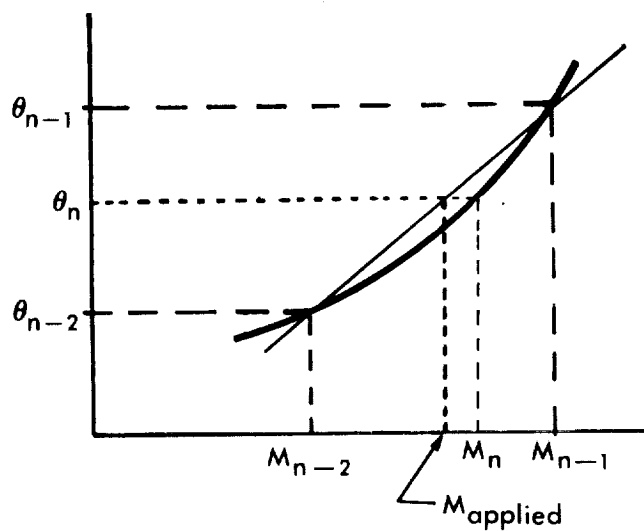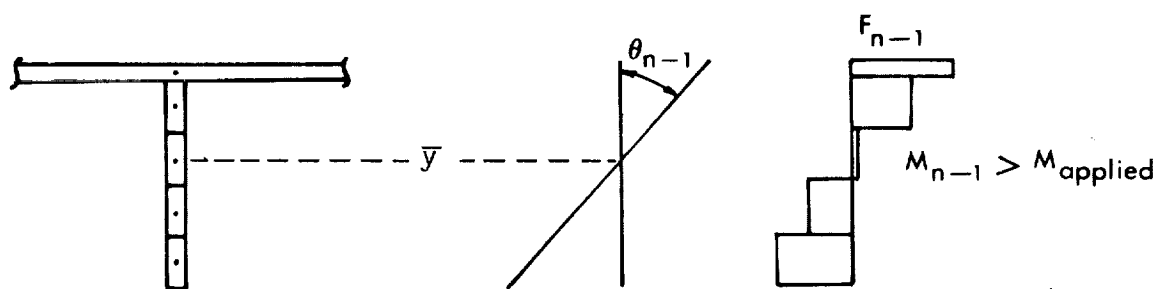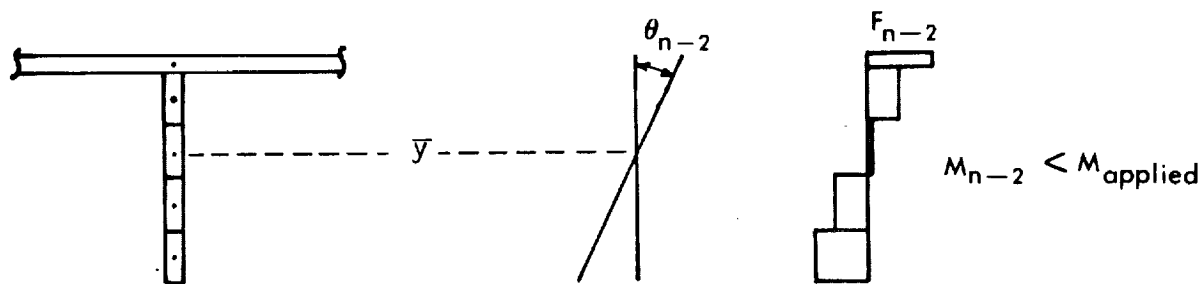
FIGURE B-11 MOMENT BALANCE ITERATION APPROACH
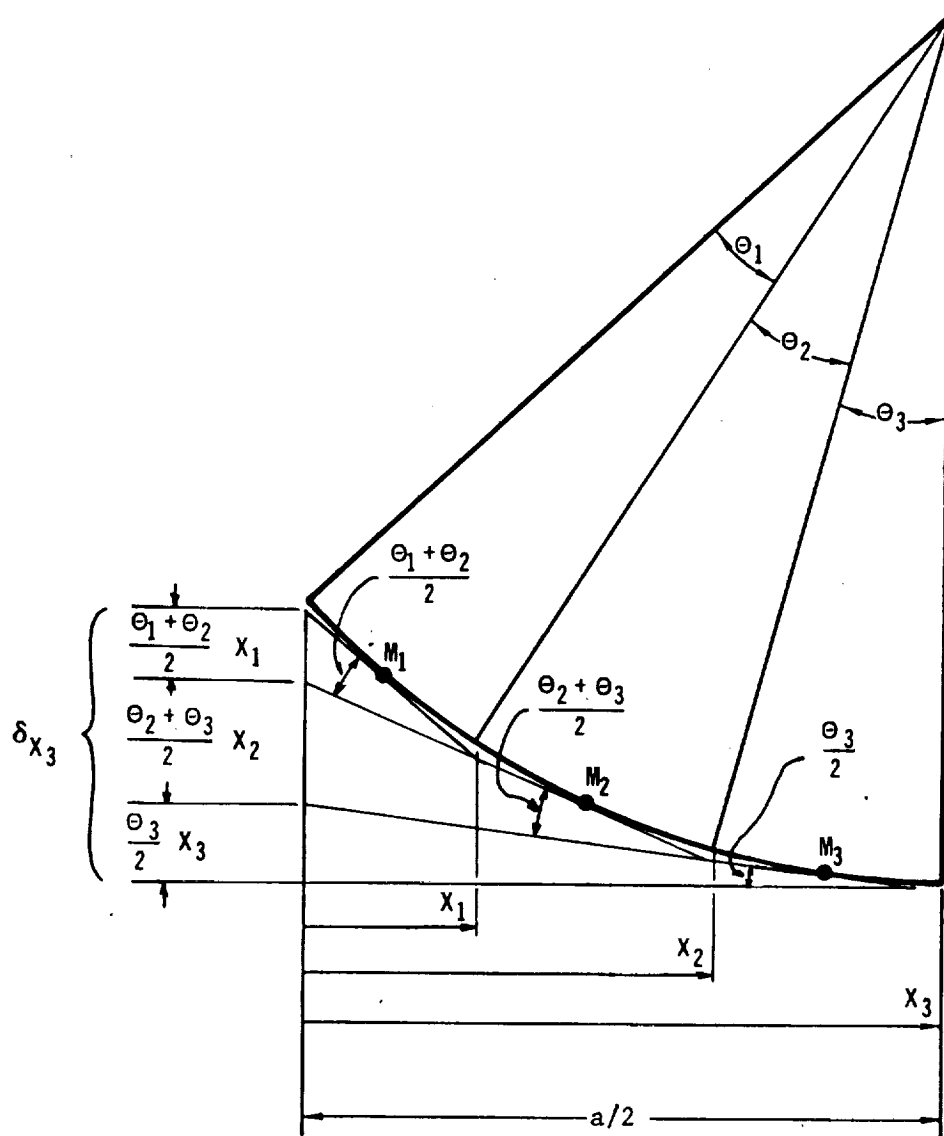
FIGURE B-12   APPROACH FOR CALCULATION OF DEFLECTIONS

B.2.9 Calculation of Creep Strains and Residual Stress

Once force balance and moment balance have been established the residual stresses and creep strains are calculated at each j element as

$$\sigma_{RESIDUAL_j} = \sigma_{e_j} - \sigma_j \tag{B-20}$$

and

$$\varepsilon_{c_j} = \varepsilon_{T_j} - \varepsilon_{e_j} = \theta_c \frac{(\overline{Y} - Y_j)}{\Delta X} - \frac{\sigma_{RESIDUAL_j}}{E} \tag{B-21}$$

In addition to calculation of residual stresses and creep strains for output purposes, these values are retained for use in subsequent analysis. Creep strains are required for use in strain hardening analysis and residual stresses are added to elastic stresses for initiation of the next analysis time step.

B.2.10 Deflection Calculations

Structural creep rotation (θ_c) and elastic rotations (θ_e) are calculated as a function of time and stored for use in numerical integration calculations for deflections.

These deflections are calculated at each station (subscript i), according to the following equations where NSTAT is the total number of beam stations in half the beam length and n is a dummy variable used to designate the beam stations

$$(i = 1 \text{ to NSTAT-2}) \quad \delta X_i = \sum_{n=1}^{i} \frac{\theta_n + \theta_{n+1}}{2} X_n + \frac{\theta_{i+1}}{2} X_i + X_i \sum_{n=i+2}^{NSTAT} \theta_n \tag{B-22}$$

$$(i = \text{NSTAT-1}) \quad \delta X_i = \sum_{n=1}^{i} \frac{\theta_n + \theta_{n+1}}{2} X_n + \frac{\theta_{NSTAT}}{2} X_{NSTAT-1} \tag{B-23}$$

$$(i = \text{NSTAT}) \quad \delta X_i = \sum_{n=1}^{i} \frac{\theta_n + \theta_{n+1}}{2} X_n + \frac{\theta_{NSTAT}}{2} X_{NSTAT-1} \tag{B-24}$$

Values of θ are either elastic rotations or creep rotations for calculation of elastic deflections and creep deflections respectively. Shown in figure B-12 is a sketch of the rotations and midspan deflection (EQN B-24) for a beam with NSTAT = 3.

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B.3 PROGRAM INPUT

The TPSC deck consists of control cards, the TPSC source deck, and input cases. End of record (EOR) cards terminate the control card deck and source deck and an end of information (EOI) card terminates the job deck. Deck setup is shown in Figure B-13. The program requires 102K of core to load and 72K to run under the KRONOS 2.1 operating system.

Input cases are stacked behind the source deck in the deck setup. The first card of each case must be a case identification card. Information listed in columns 1 through 50 on this card will be printed as a heading in the output for that case.

The remainder of data is input using a user oriented "namelist" format. This input follows the identification card for each case. The first card following the identification card must have a $ in column 2 followed immediately by the name CREEP with no embedded blanks. Succeeding variables are read until a second $ is encountered. Input variables are defined following the first $. All except the last variable must be followed by a comma and the first column of each card is ignored. Constant fields may not include imbedded blanks. Blanks, however, may appear elsewhere in data records.

Examples of the input data are shown in figure B-14. Values for variable names beginning with the letters I, N and K are input without decimal points. Commas must immediately follow these values. Subscripted variables such as PRESS(N) are input as PRESS(1) = followed by the values for PRESS (1), PRESS (2), PRESS (3), etc (see example problem 2).

The general table lookup routine used in defining temperature distributions (XTEMP(N) and YTEMP(N)) and elastic modulus data (ETEMP(N)) requires special input considerations. Example input for XTEMP(N), is shown in figure B-14. This is typical also for YTEMP(N) and ETEMP(N). The values 0., 1., K, 0., X_1, X_2,....X_k, T_1,

B-30
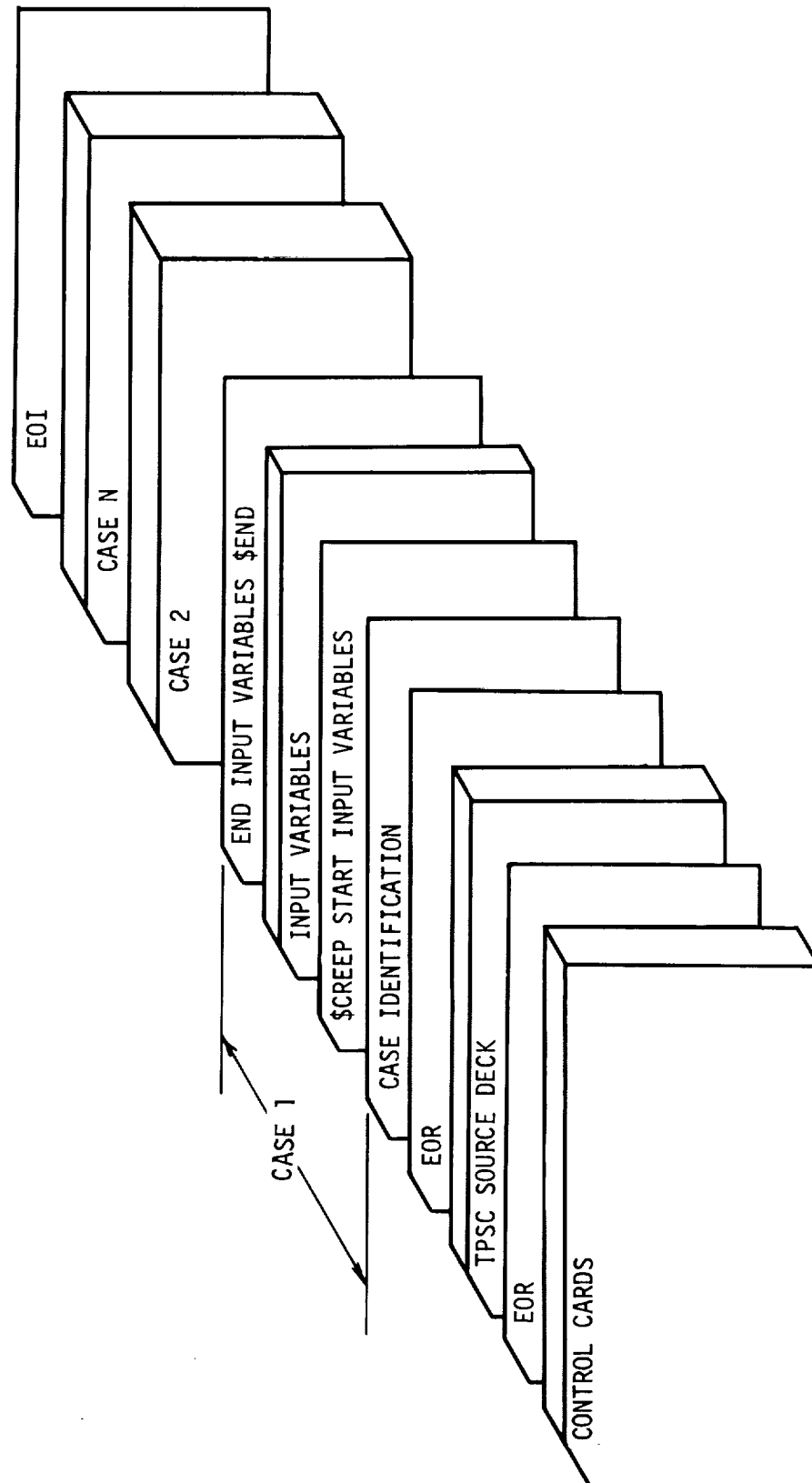
Figure B-13 TPSC PROGRAM DECK SETUP

EOI

CASE N

CASE 2

END INPUT VARIABLES $END

INPUT VARIABLES

$CREEP START INPUT VARIABLES

CASE IDENTIFICATION

CASE 1

EOR

TPSC SOURCE DECK

EOR

CONTROL CARDS

XTEMP(1) = 0.,.1,.2,,0.,,0.,,3.5,.8,1.0,$END

TEMP(1) = 1000., 1200., 1400.,

XLGTH = 3.5, PRESS(1) = 5., 10., 8.1,

$CREEP, NTIME = 3, NCYCLE = 100,

DATA CASE NUMBER 1

COL 2
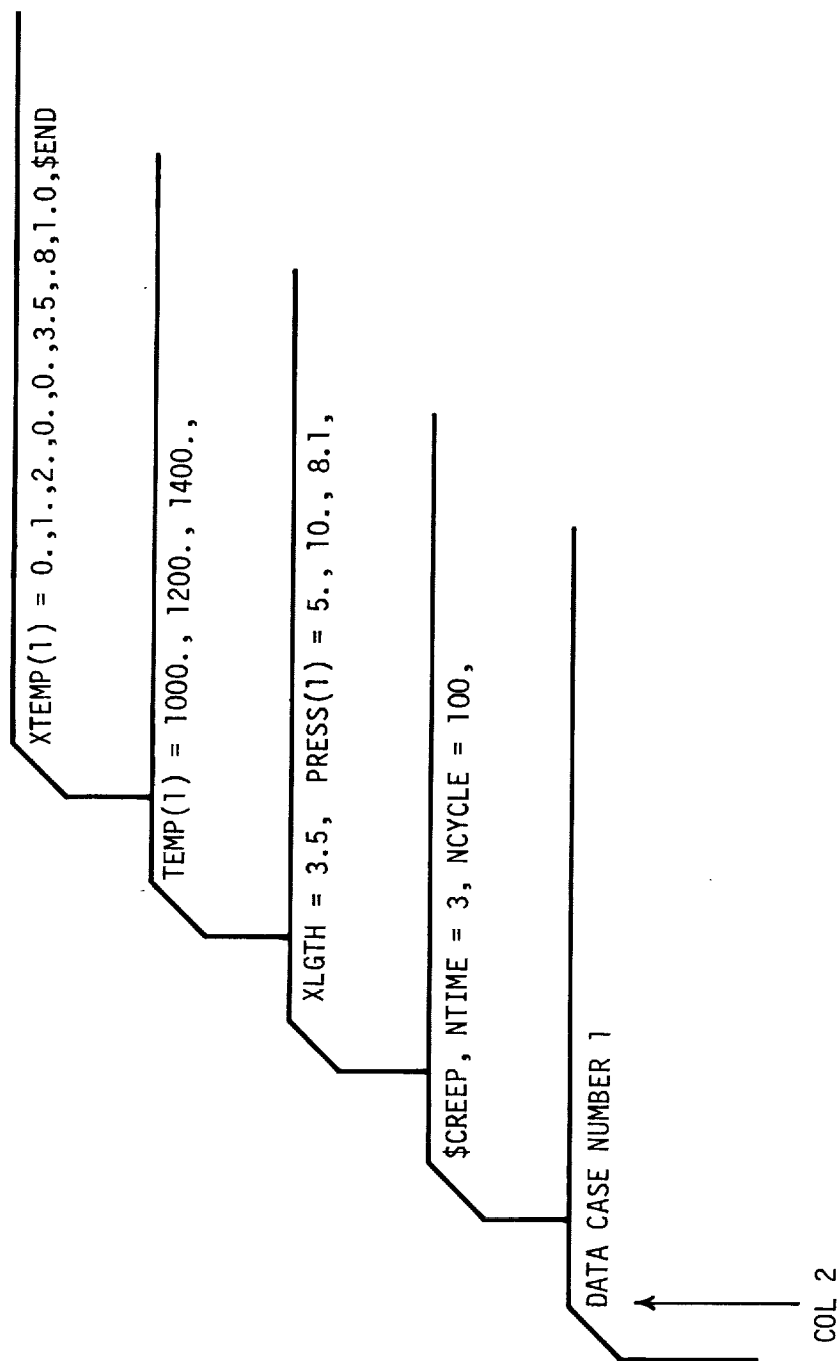
Figure B-14 EXAMPLE INPUT

$T_2, \ldots T_k$ are input following the variable name XTEMP(1) where K is the number of

sets of location-temperature data (section 2.3), $X_1, \ldots X_k$ are the corresponding

locations along the panel length, and $T_1, \ldots T_k$ are the associated normalized

temperatures. The first, second, and fourth values (0., 1., 0.) are required input.

Listings of the input variables for the TPSC program are given in Tables B-1

through B-7. For variables where default values are provided, no input need be made

except to use options other than those provided for by the default. Example problem

inputs are given in Section B-8.

Table B.1 INPUT FOR ANALYSIS CONTROL

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Option for Elastic Analysis (Ref. Section B.2.5) ° Creep and Elastic Analysis ° Elastic Analysis Only	INDELA	0 (Default) 1
Number of Analysis Cases (Input in First Case Only)	NEWCAS	1 (Default)
Option for Creep Strain Accumulation Theory (Ref. Section B.2.4) ° Time Hardening ° Strain Hardening	HARDOP	1. (Default) 2.
Maximum Time (Hours) This Input Required When HARDOP = 2. (Ref. Section B.2.4)	TMAX	
Option for Linear Creep Stress-Strain Below Stress = 1. ° Creep Equation Used ° Linear Stress-Strain EQN Override	INDSTR	0 (Default) 1
Option for TPS Panel Cross Section Geometry (Ref. Section B.2.1) ° Rib. ° Corrugation ° Zee	INDGEO	1 2 3
Option for Incorporating Beaded Skin into Geometry (Ref. Section B.2.1) ° No Bead ° Bead Included	INDBD	0 (Default) 1
Number of Stations Along Panel Length Used In The Analysis (Ref. Section B.2.1)	NSTAT	6 (Default)
Number of Sections Through Panel Depth Used in The Analysis (Ref. Section B.2.1)	SEC NSECT	10. (Default) 10 (Default)

INPUT FOR ANALYSIS CONTROL (Continued)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Option for Units Of Time In Input Creep Equation ° Hours ° Minutes	ITIME	 0 (Default) 1
Option for Units of Temperature In Input Creep Equation ° °K/1000. ° °F/1000.	IEQNTP	 0 (Default) 1
Option for Units of Stress In Input Creep Equation ° MPa ° KSI	IEQNST	 0 (Default) 1
Option for Temperature Input Units ° °K ° °F	IINTP	 0 (Default) 1
Option for Pressure And Load Input Units ° Pa, KILOS ° psi, Lbs.	ILOAD	 0 (Default) 1
Option for Dimension Input Units ° cm. ° in.	IDIMEN	 0 (Default) 1
Option for Input of Initial Residual Stresses ° Initial Values = 0. ° Values Input	IRESID	 0 (Default) 1
Initial Residual Stress Values	RESSIN (I,J)	

Table B-2 INPUT FOR OUTPUT CONTROL (Ref. Section B.1)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Option For Printing Creep Deflections at Each Trajectory Step In First Cycle ° Print Not Req'd. ° Print Req'd.	INCYC	 0 1 (Default)
Total Number of Cycles at Which Creep Deflection, Creep Strain, and Residual Stress Output Are Desired	NUMCYC	
Cycle Numbers at Which Output Is To Be Printed.	KCYCLE (N)	

Table B-3 INPUT FOR PANEL GEOMETRY DEFINITION (REF. SECTION B.2.1)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Panel Unsupported Length	XLGTH	
Panel Width	PANWID	
Panel Cross Section	DEPTH	
Stiffener Spacing	PITCH	
Panel Skin Thickness	TS	

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INPUT FOR RIB-STIFFENED CROSS SECTION (REF. SECTION B.2.1)
(INDGEO = 1)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Rib Thickness	TR	
Number of Ribs Across	NRIB	
Distance From Outer Panel Rib to Panel Edge	RIBFLG	

INPUT FOR CORRUGATION STIFFENED CROSS SECTION (REF. SECTION B.2.1)
(INDGEO = 2)

DEFINTION	INPUT VARIABLE NAME	INPUT VALUE
Corrugation Thickness	TC	
Number of Corrugations Across Panel Width	NCOR	
Corrugation Angle	PHICOR	
Corrugation Length in Contact With Skin	FLAT	
Edge Distance in Excess of Normal Pitch Length	EDGE	

INPUT FOR ZEE STIFFENED CROSS SECTION (REF. SECTION B.2.1)
(INDGEO = 3)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
ZEE Thickness	TZEE	
Number of Zee Stiffeners Across Panel Width	NZEE	
ZEE Stiffener Flange Dimensions	ZEESF ZEESF1 ZEEFF ZEEFF1	
Panel Edge .Distance	ZPNED1 ZPNED2	

INPUT FOR SKIN BEAD GEOMETRY (REF. SECTION B.2.1)
(INDBD = 1)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Bead Width	BWID	
Bead Depth	BDEP	
Bead Radius (Sign of BRAD Indicates Positive or Negative Bead Direction)	BRAD	

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Table B-4   INPUT FOR TRAJECTORY AND LOAD DEFINITION
(REF. SECTION B.2.2)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Option For Type of Applied Load ° Uniform pressure ° Point loads	INDLOD	0 (Default) 1
Number of Time Steps in Trajectory Idealization	NTIME	
Time at End of Each Trajectory Time Step	DXTIME (N)	
Pressure Load at Each Trajectory Time Step (INDLOD = 0)	PRESS (N)	
Point Load at Each Trajectory Time Step (INDLOD = 1)	PLOAD (N)	
Distance from Beam Support to Applied Load (Input for INDLOD = 1)	ALEN	
Number of cycles to Be Analyzed	NCYCLE	
Option for Plate Bending Moment Calculations ° Analysis based on beam loads ° Plate moments used in analysis	INDPLA	0 (Default) 1
Stiffness of Panel Edge Support. (Moment of inertia). Input for INDPLA = 1.	ESTIFF	

INPUT FOR TRAJECTORY AND LOAD DEFINITION (Continued)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Option for Inputing Panel Stiffness in Transverse Panel Direction (Moment of Inertia Per Inch Of Panel Length) ° $I = TS^3/12 \ (1-\nu)^2$ ° I is input	INDD2	0 (Default) 1
Value of Input Transverse Panel Stiffness	DETWO	

TABLE B-5   INPUT FOR PANEL TEMPERATURE DISTIRBUTION
(REF. SECTION B.2.3)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Midspan Panel Skin Temperature At Each Trajectory Time Step	TEMP (N)	
Option for Temperature As A Function of Panel Length ° Temperature constant along the panel length ° Temperature variation along the panel length defined by equation coefficients ° Temperature variation along the panel length defined by Table lookup	INDTFL	0 (Default) 0 1
Equation Coefficients for Temperature Distribution along Length	C(1)	
Temperature Distribution along Length Defined by Table Lookup k = number of points in Table	XTEMP(1) = 0.,1.,k,0., $X_{1,k}$, $T_{x1,k}$	
Option for Temperature As A Function of Panel Depth ° Temperature constant through the panel depth ° Temperature variation through the panel depth defined by equation coefficients ° Temperature variation through the panel depth defined by Table lookup	INDTFD	0 (Default) 0 1
Equation Coefficients for Temperature Distribution Through the Panel Depth	D(1)	

INPUT FOR PANEL TEMPERATURE DISTRIBUTION (Continued)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Temperature Distribution Through Depth Defined By Table Lookup k = Number of points in Table	YTEMP (1) = 0.,1.,k,0., $Y_{1,k}$, $T_{y1,k}$	

Temperature Variation in Panel
  ° Constant over Panel
  ° Variation defined by equation or Table
	ITCON	1 (Default)
		0

Temperature Variation in Trajectory
  ° Constant
  ° Variable
	NTCON	1 (Default)
		0

TABLE B-6   INPUT FOR MATERIAL PROPERTY DEFINITION

(REF. SECTION B.2.3)

DEFINITION	INPUT VARIABLE NAME	INPUT VALUE
Poisson's Ratio (Req'd. if INDPLA = 1)	XNU	
Option for Definition of Elastic Modulus Data ° Constant modulus ° Modulus defined by equation ° Modulus defined by table lookup	INDMOD	 0 (Default) 0 1
Equation Coefficients for Elastic Modulus as Function of Temperature	ECOEFF (1)	
Tabular Data for Elastic Modulus as A Function of Temperature	ETEMP (1) = 0., 1., k, 0., $T_{1,k}$, $E_{1,k}$	

TABLE B-7   INPUT FOR CREEP PROPERTY DEFINITION

Material creep properties are defined through the input of coefficients

(Z) to the linear equation

$$\ln \epsilon = Z_1 X_1 + Z_2 X_2 + Z_3 X_3 + \ldots \ldots + Z_N X_N$$

<div align="center">or</div>

(B-25)

$$\epsilon = \exp (Z_1 X_1 + Z_2 X_2 + Z_3 X_3 + \ldots \ldots + Z_N X_N)$$

In this equation, the value of X_1 is defined as 1 and X_2 through

X_N are terms in time (t), stress (σ), and temperature (T) listed in

table B-7 section. Only the terms required need to be input.

TABLE B-7 INPUT FOR CREEP PROPERTY DEFINITION
(CONTINUED)

COEFFICIENT NAME	CREEP EQUATION TERM	
	LOGARITHMIC FORM	EXPONENTIAL FORM
Z(1)	Z_1	e^{Z_1}
Z(2)	$Z_2 \sigma$	$e^{Z_2 \sigma}$
Z(3)	$Z_3 T$	$e^{Z_3 T}$
Z(4)	$Z_4 t$	$e^{Z_4 t}$
Z(5)	$Z_5 (\frac{1}{T})$	$e^{Z_5/T}$
Z(6)	$Z_6 \ln t$	t^{Z_6}
Z(7)	$Z_7 \ln \sigma$	σ^{Z_7}
Z(8)	$Z_8 \ln T$	T^{Z_8}
Z(9)	$Z_9 \sigma^2$	$e^{Z_9 \sigma^2}$
Z(10)	$Z_{10} \sigma^3$	$e^{Z_{10} \sigma^3}$

INPUT FOR CREEP PROPERTY DEFINITION (Continued)

COEFFICIENT NAME	CREEP EQUATION TERM	
	LOGARITHMIC FORM	EXPONENTIAL FORM
Z(11)	$Z_{11}\left(\frac{1}{T}\right)^2$	e^{Z_{11}/T^2}
Z(12)	$Z_{12}\left(\frac{1}{T}\right)^3$	e^{Z_{12}/T^3}
Z(13)	$Z_{13}\sigma T$	$e^{Z_{13}\sigma T}$
Z(14)	$Z_{14}\left(\frac{\sigma}{T}\right)$	$e^{Z_{14}(\sigma/T)}$
Z(15)	$Z_{15}(\sigma T)^2$	$e^{Z_{15}(\sigma T)^2}$
Z(16)	$Z_{16}(\sigma T)^3$	$e^{Z_{16}(\sigma T)^3}$
Z(17)	$Z_{17}\left(\frac{\sigma}{T}\right)^2$	$e^{Z_{17}(\sigma/T)^2}$
Z(18)	$Z_{18}\left(\frac{\sigma}{T}\right)^3$	$e^{Z_{18}(\sigma/T)^3}$
Z(19)	$Z_{19}\,(\ln\sigma)^2$	$\sigma^{Z_{19}\ln\sigma}$
Z(20)	$Z_{20}\,(\ln\sigma)^3$	$\sigma^{Z_{20}(\ln\sigma)^2}$

INPUT FOR CREEP PROPERTY DEFINITION (Continued)

COEFFICIENT NAME	CREEP EQUATION TERM	
	LOGARITHMIC FORM	EXPONENTIAL FORM
Z(21)	$Z_{21} \sigma \ln T$	$T^{Z_{21}\sigma}$
Z(23)	$Z_{23} \ln\sigma \ln T$	$\sigma^{Z_{23}\ln T}$
Z(22)	$Z_{22} T\ln\sigma$	$\sigma^{Z_{22}T}$
Z(24)	$Z_{24} t\sigma T$	$e^{Z_{24}t\sigma T}$
Z(25)	$Z_{25} (t\sigma T)^2$	$e^{Z_{25}(t\sigma T)^2}$
Z(26)	$Z_{26} (t\sigma T)^3$	$e^{Z_{26}(t\sigma T)^3}$
Z(27)	$Z_{27} t^2$	$e^{Z_{27}t^2}$
Z(28)	$Z_{28} t^3$	$e^{Z_{28}t^3}$
Z(29)	$Z_{29}(\ln t)^2$	$t^{Z_{29}\ln t}$
Z(30)	$Z_{30}(\ln t)^3$	$t^{Z_{30}(\ln t)^2}$

INPUT FOR CREEP PROPERTY DEFINITION (Continued)

COEFFICIENT NAME	CREEP EQUATION TERM	
	LOGARITHMIC FORM	EXPONENTIAL FORM
Z(31)	$Z_{31}T^2$	$e^{Z_{31}T^2}$
Z(32)	$Z_{32}T^3$	$e^{Z_{32}T^3}$
Z(33)	$Z_{33}(\ln t)^2$	$T^{Z_{33}\ln T}$
Z(34)	$Z_{34}(\ln T)^3$	$T^{Z_{34}(\ln T)^2}$
Z(35)	$Z_{35}\sigma\ln t$	$t^{Z_{35}\sigma}$
Z(36)	$Z_{36}T\ln t$	$t^{Z_{36}T}$
Z(37)	$Z_{37}t\ln\sigma$	$\sigma^{Z_{37}t}$
Z(38)	$Z_{38}t\ln T$	$T^{Z_{38}t}$
Z(39)	$Z_{39}\ln\sigma\ln t$	$\sigma^{Z_{39}\ln t}$
Z(40)	$Z_{40}\ln t\ \ln T$	$t^{Z_{40}\ln T}$

B-51

INPUT FOR CREEP PROPERTY DEFINITION (Continued)

COEFFICIENT NAME	CREEP EQUATION TERM	
	LOGARITHMIC FORM	EXPONENTIAL FORM
$Z(41)$	$Z_{41} \dfrac{\ln\sigma}{T}$	$\sigma^{Z_{41}/T}$
$Z(42)$	$Z_{42} \dfrac{\ln t}{T}$	$t^{Z_{42}/T}$
$Z(43)$	$Z_{43} \dfrac{\ln t \, \ln\sigma}{T}$	$\sigma^{Z_{43}\ln t/T}$
$Z(44)$	$Z_{44} t\sigma$	$e^{Z_{44} t\sigma}$
$Z(45)$	$Z_{45} tT$	$e^{Z_{45} tT}$

B.4 PROGRAM OUTPUT

Program output includes a listing of input variables, calculated elastic stresses at each panel station and trajectory step, panel geometry definition, trajectory load and temperature definition, creep strain equation definition, elastic deflections, creep deflections, creep strain distributions, and residual stress distributions. Creep deflections are printed at times within the first cycle and at the end of each requested cycle (KCYCLE). The example problems in Section 8 show typical program output.

Generally the output is automatic and not controlled by the user. The following items are, however, at the option of the program user.

(a) Printout of calculated creep deflections at the end of each trajectory time step in the first cycle are controlled by the variable INCYC. These deflections are printed as a default unless INCYC = 0 is input.

(b) The cycles at which calculated creep deflections, creep strain distributions, and residual stress distributions are printed, are controlled by the input variables NUMCYC and KCYCLE(N). The variable NUMCYC is the total number of cycles at which printout is required (maximum = 10) and KCYCLE(N) is the designated cycle number for printout.

(c) Both analysis and output are controlled by the number of panel length increments and depth increments defined by the input variables NSECT, SEC, NSTAT, and NBSECT (ref. Section B.3). Output of stresses, deflections, and strains are calculated and printed at locations along the panel length and through the panel depth as defined by these input variables in conjunction with the panel geometry (Section B.2.1).

B.5 PROGRAM DIAGNOSTICS

Three types of diagnostic statements are included in the TPSC program to provide user information where problems may be occurring in the analysis.

(1)   "CORRUGATION INPUT DATA YIELDS A NEGATIVE S LENGTH"

This information is printed out and the analysis terminated when the calculated corrugation flat length dimension S (Ref. Section B.2.1) is negative The geometry definition (PHICOR, DEPTH, FLAT, PITCH) should be checked for input error.

(2)   "ERROR IN TABLE-LOOKUP ROUTINE AT $\left\{ \begin{array}{c} XIN \\ YIN \\ TIN \end{array} \right\}$ = __A__ ."

A is the panel station X(XIN), the panel depth increment (YIN), or the temperature (TIN) which exceeds the bounds of the appropriate input table for temperature as a function of length, temperature as a function of depth, and elastic modulus as a function of temperature, respectively. The table lookup input data should be checked to insure that the range of data in the table extends over the range needed for analysis.

(3) "WARNING - TWENTY ITTERATIONS ON STRESS IN THE HARDENING ROUTINE
     BEAM STATION = _____, SECTION (J) = _____, CYCLE = _____, STEP = _____
     ANALYSIS PROCEEDING WITH STRESS UNCHANGED."

This diagnostic message indicates that the iteration process for stress (Reference Section B.2.6) did not converge. The stress is defined as that at the end of the previous time step and analysis continues. When this occurs, the form of the input empirical equation should be checked.

B.6 COMPUTER TIME REQUIREMENTS

Computer (CPU) time data compiled for analysis cases using the TPSC program are shown in Figure B-15. These data points are plotted against a value N which is the product of the number of increments through the panel depth (NSECT + NBSECT), the number of segments along the panel length (NSTAT), the number of time steps in the load-temperature trajectory (NTIME), and the number of cycles being analyzed. Data, shown in the figure are for analysis conducted using the time hardening theory of creep accumulation program option.

Because additional iterations are required in analysis using the strain hardening theory of creep accumulation, a factor of 1.8 (factors for specific cases typically range from 1.3 to 2.4) should be applied to the range shown in Figure B-15 for this option. In addition, the data plotted are for separate runs. Running of multiple cases results in a somewhat lower per case computer time.

Variations in required computer time are expected from run to run depending on times required to converge on stresses, load balances, and moment balances in the program. The data, obtained in analysis for prediction of creep deflections in subsize and full size panels, are presented to provide computer time guidelines for the TPSC program user.

FIGURE B-15 TPSC COMPUTER TIME REQUIREMENTS

$$N = \left[\frac{(NSECT + NBSECT) \ (NSTAT) \ (NTIME) \ (NCYCLE)}{} \right] /100$$

CDC 6500 COMPUTER TIME (CPU) ~ SECONDS
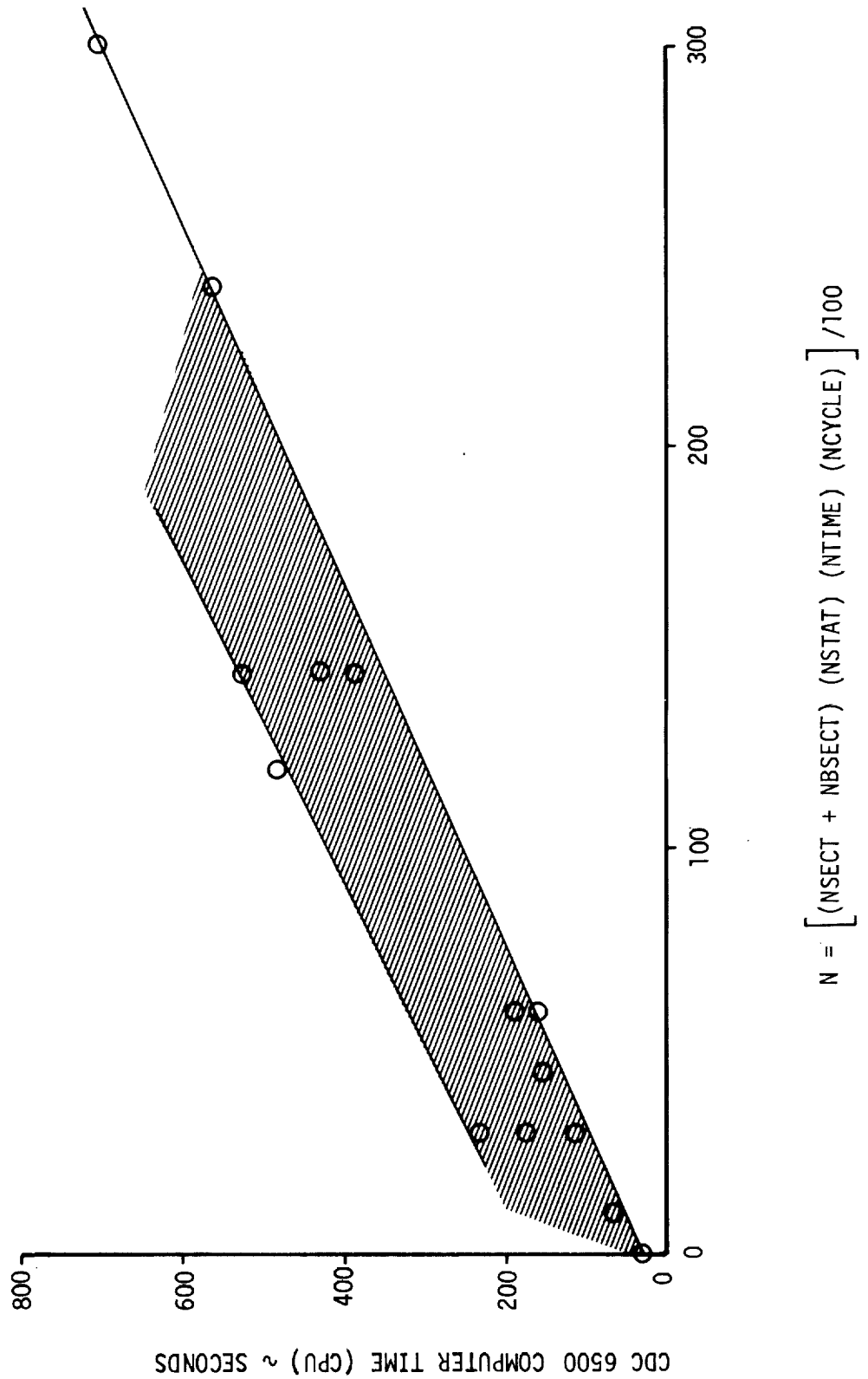
B.7 ANALYSIS SENSITIVITY TO PANEL ELEMENT SIZE

Limited studies have been conducted to investigate the sensitivity of the TPSC program prediction capability to the number of sections along the panel length (NSTAT) and increments through the panel depth (NSECT). Shown in Figure B-16 are typical midspan elastic and creep deflection predictions as a function of these variables. This example is based on an 11-inch titanium panel subjected to a uniform pressure load. These studies have demonstrated that a minimum of these sections are needed to maintain prediction precision and, based on study results, the values NSTAT = 6 and NSECT = 10 are default values in the program. Because more sections are required to define horizontal sections and flange sections for the Z stiffened TPS and corrugation stiffened TPS than for the rib stiffened concept, a minimum value for NSECT is recommended as 8 for the rib, 10 for the corrugation, and 12 for the Z stiffened concepts. Also the effects of NSECT on creep deflection prediction capability will be somewhat dependent on the degree of nonlinearity of the input creep strain equation with respect to stress. Therefore, more sections should be included for equations which are very nonlinear in stress.
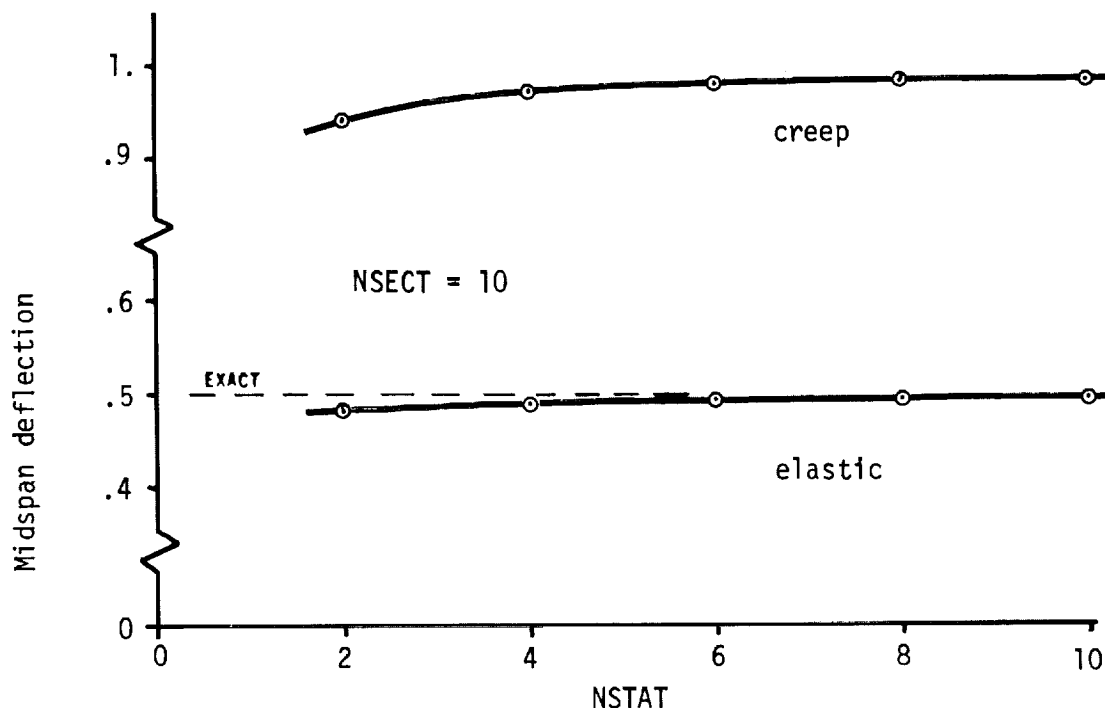
(a) SENSITIVITY TO SECTIONS ALONG PANEL LENGTH
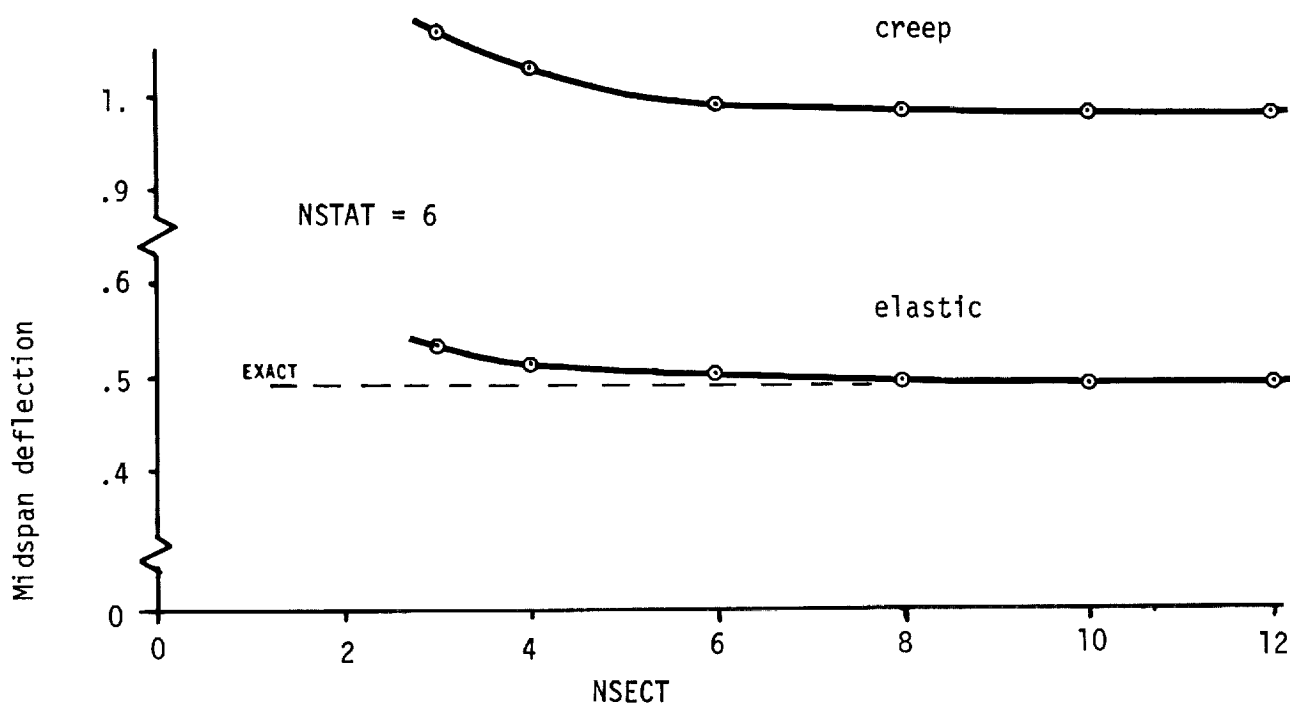
(b) SENSITIVITY TO INCREMENTS THROUGH PANEL DEPTH

FIGURE B-16   TYPICAL SENSITIVITY OF PREDICTION TO ELEMENT SIZE

B.8 EXAMPLE PROBLEMS

The following two example problems are provided to demonstrate the input for the major programs options. Section B.3 should be consulted for default values for variable means not included in the input. These default values apply when the variable is not input.

EXAMPLE PROBLEM 1

Example problem 1 demonstrates analysis capability for the rib stiffened panel shown in Figure B-17(a). This simply supported panel is loaded with two point loads located 3.62 inches from the panel supports as shown in Figure B-17(b). In the example, the panel is subjected to ten constant load and temperature cycles of 20 minute duration each (Figure B-17(c)) and the time hardening theory of creep accumulation is used. The panel temperature is a function of panel length as shown in Figure B-17(d). Elastic modulus is defined as a function of temperature as 12.3×10^6 psi at 725°F and 11.8×10^6 psi at 825°F (note this covers panel temperature range of 769°F (.932 x 825, Figure B-17(d)) to 825°F). U.S. Customary units are used in the input data. The following creep equation for Titanium (Reference 2) is used:

$$\ln\varepsilon = -26.22982 + 26.2485T + .000126\sigma^2 + 1.40406 \ln\sigma + .46894 \ln t$$

where t = time, hours

T = temperature, °F/1000

σ = stress, ksi

Deflection, strain, and stress outputs are requested after 1, 3, and 10 cycles are data given through the panel depth and along its length are output according to the default values of NSECT (10) and NSTAT (6), respectively.

Input and output for example problem 1 follows.
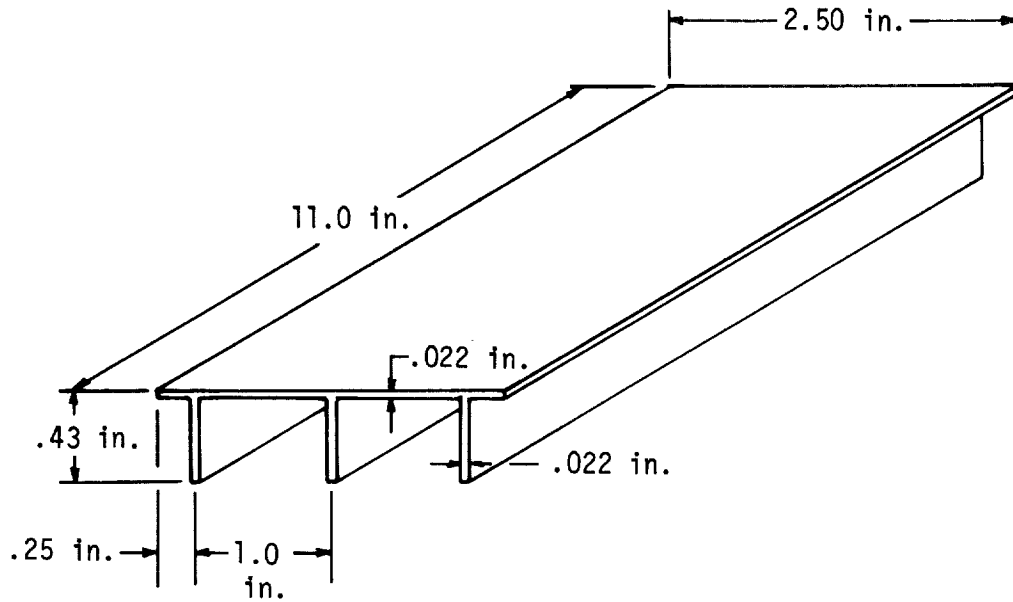
(a) PANEL GEOMETRY
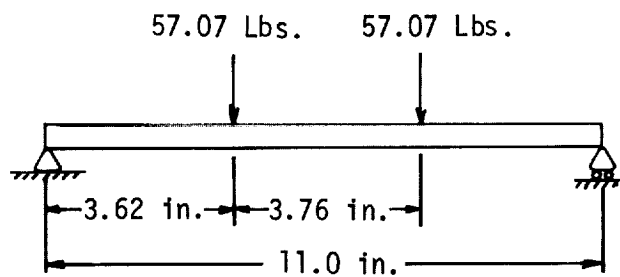
(b) PANEL LOAD
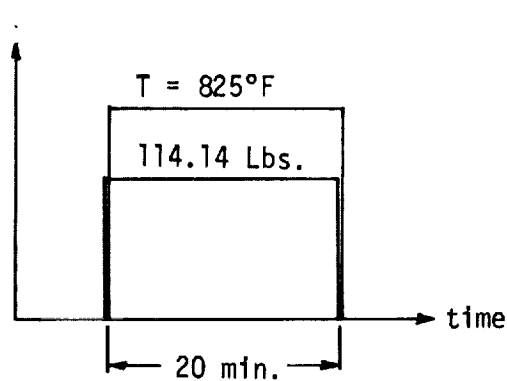
(c) TRAJECTORY
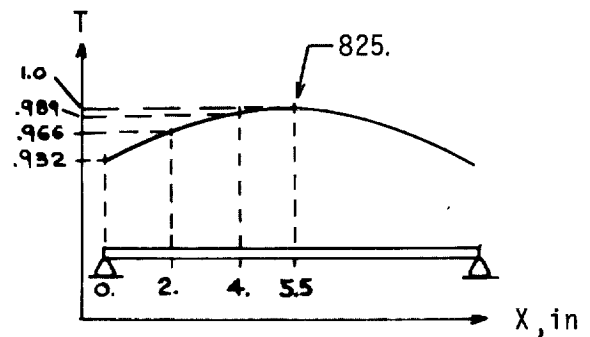
(d) TEMPERATURE DISTRIBUTION

FIGURE B-17 EXAMPLE PROBLEM 1

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```
NEWCAS=1, $END
INDMOD=1,ETEMP(1)=0.,1.,2.,0.,725.,825.,12.3E06,11.8E06,
TEMP(1)=825.,XTEMP(1)=0.,1.,4.,0.,0.,2.,4.,5.5.,932.,966.,989.,1.0,
INDTFL=1,ITCON=0,
Z(1)=-26.22982,Z(3)=26.24850,Z(9)=.000120,Z(7)=1.40406,Z(6)=.46894,
INDLOD=1,ALEN=3.62,PLOAD(1)=114 145,DXTIME(1)=20.,
NTIME=1,NCYCLE=10,NUMCYC=3,KCYCLE(1)=1,3,10,
DEPTH=.43,PITCH=1.0,RIBFLG=.25,
PANWID=2.50,XLGTH=11.0,NRIB=3,TS=.022,TR=.022,
$CREEP INDGEO=1,ITIME=1,IEQNST=1,IINTP=1,IINTP=1,ILOAD=1,IDIMEN=1,
TPSC EXAMPLE PROBLEM 1
```

EXAMPLE PROBLEM 1 INPUT

EXAMPLE PROBLEM 1 OUTPUT

```
$CREEP
DEPTH   =  0.43E+00,
PHICOR  =  0.0,
PITCH   =  0.1E+01,
FLAT    =  0.0,
EDGE    =  0.0,
NCOR    =  0,
TS      =  0.22E-01,
TC      =  0.0,
XLGTH   =  0.11E+02,
TR      =  0.22E-01,
NRIB    =  3,
RIBFLG  =  0.25E+00,
ZPNE01  =  0.0,
ZPNE02  =  0.0,
NZEE    =  0,
TZEE    =  0.0,
ZEESF   =  0.0,
ZEESF1  =  0.0,
ZEEFF   =  0.0,
ZEEFF1  =  0.0,
BWID    =  0.0,
BDEP    =  0.0,
BRAD    =  0.0,
PRESS   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
TEMP    =  0.825E+03,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
DXTIME  =  0.2E+02,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
PLOAD   =  0.114145E+03,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
ALEN    =  0.362E+01,
XNU     =  0.0,
PANWID  =  0.25E+01,
C       =  0.1E+01,  0.0,  0.0,  0.0,
D       =  0.1E+01,  0.0,  0.0,  0.0,
E       =  0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0, 0.0,
```

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

EXAMPLE PROBLEM 1 OUTPUT

```
NTIME    =  1,
XTEMP    =  0.0,  0.1E+01,  0.4E+01,  0.0,  0.0,  0.2E+01,  0.4E+01,  0.55E+01,  0.932E+00,  0.966E+00,  0.989E+00,
            0.1E+01,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
NEWCAS   =  1,
YTEMP    =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
EMOD     =  0.0,
ETEMP    =  0.0,  0.1E+01,  0.2E+01,  0.0,  0.725E+03,  0.825E+03,  0.123E+08,  0.116E+08,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
INCGEO   =  1,
INDBD    =  0,
INDLOD   =  1,
INDSUP   =  0,
INDPLA   =  0,
INDTFL   =  1,
INDTFD   =  0,
KCYCLE   =  1,  3,  10,  0,  0,  0,  0,  0,  0,  0,
INCMOD   =  1,
INDELA   =  0,
NCYCLE   =  10,
NUMCYC   =  3,
ITCON    =  0,
NTCON    =  1,
ECOEFF   =  0.0,  0.0,  0.0,  0.0,
Z        = -0.262292E+02,  0.0,  0.262485E+02,  0.0,  0.0,  0.46894E+00,  0.140406E+01,  0.0,  0.12E-03,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
HARDOP   =  0.1E+01,
TMAX     =  0.0,
INCYC    =  1,
ITIME    =  1,
IEONTP   =  0,
IINTF    =  1,
IDIMEN   =  1,
ILOAD    =  1,
IEONST   =  1,
NSTAT    =  6,
SEC      =  0.1E+02,
NSECT    =  10,
NBSECT   =  6,
IRESID   =  0,
RESSIN   =  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
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MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

EXAMPLE PROBLEM 1 OUTPUT (Continued)

```
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,    0.0,
```

ESTIFF = 0.0,
INDO2   = 0,
INDSTR = 0,
DETWO   = 0.0,
$END

EXAMPLE PROBLEM 1 OUTPUT (Continued)

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= .917

TRAJECTORY TIME STEP 1

J	AREA(SQ.IN)	Y(IN)	STRESS(PSI)
1	2.99200E-03	2.26667E-02	7.07220E+03
2	2.99200E-03	6.80000E-02	6.08774E+03
3	2.99200E-03	1.13333E-01	5.10328E+03
4	2.99200E-03	1.58667E-01	4.11882E+03
5	2.99200E-03	2.04000E-01	3.13436E+03
6	2.99200E-03	2.49333E-01	2.14990E+03
7	2.99200E-03	2.94667E-01	1.16544E+03
8	2.99200E-03	3.40000E-01	1.80982E+02
9	2.99200E-03	3.85333E-01	-8.03478E+02
10	5.50000E-02	4.19000E-01	-1.53458E+03

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 1.333

TRAJECTORY TIME STEP 1

J	AREA(SQ.IN)	Y(IN)	STRESS(PSI)
1	2.99200E-03	2.26667E-02	2.12166E+04
2	2.99200E-03	6.80000E-02	1.82632E+04
3	2.99200E-03	1.13333E-01	1.53098E+04
4	2.99200E-03	1.58667E-01	1.23565E+04
5	2.99200E-03	2.04000E-01	9.40306E+03
6	2.99200E-03	2.49333E-01	6.44971E+03
7	2.99200E-03	2.94667E-01	3.49633E+03
8	2.99200E-03	3.40000E-01	5.42947E+02
9	2.99200E-03	3.85333E-01	-2.41043E+03
10	5.50000E-02	4.19000E-01	-4.60375E+03

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 2.750

TRAJECTORY TIME STEP 1

J	AREA(SQ.IN)	Y(IN)	STRESS(PSI)
1	2.99200E-03	2.26667E-02	3.53610E+04
2	2.99200E-03	6.80000E-02	3.04387E+04
3	2.99200E-03	1.13333E-01	2.55164E+04
4	2.99200E-03	1.58667E-01	2.05941E+04
5	2.99200E-03	2.04000E-01	1.56718E+04
6	2.99200E-03	2.49333E-01	1.07495E+04
7	2.99200E-03	2.94667E-01	5.82721E+03
8	2.99200E-03	3.40000E-01	9.04912E+02
9	2.99200E-03	3.85333E-01	-4.01739E+03
10	5.50000E-02	4.19000E-01	-7.67292E+03

B-65

EXAMPLE PROBLEM 1 OUTPUT (Continued)

CASE   1 ANALYSIS
ELASTIC STRESSES AT X= 3.667

TRAJECTORY TIME STEP   1

J	AREA(SQ.IN)	Y(IN)	STRESS(PSI)
1	2.99200E-03	2.26667E-02	5.58575E+04
2	2.99201E-03	6.80000E-02	4.80821E+04
3	2.99200E-03	1.13333E-01	4.03067E+04
4	2.99200E-03	1.58667E-01	3.25312E+04
5	2.99200E-03	2.04000E-01	2.47558E+04
6	2.99200E-03	2.49333E-01	1.69803E+04
7	2.99200E-03	2.94667E-01	9.20488E+03
8	2.99200E-03	3.40000E-01	1.42943E+03
9	2.99200E-03	3.85333E-01	-6.34601E+03
10	5.50000E-02	4.19000E-01	-1.21204E+04

CASE   1 ANALYSIS
ELASTIC STRESSES AT X= 4.583

TRAJECTORY TIME STEP   1

J	AREA(SQ.IN)	Y(IN)	STRESS(PSI)
1	2.99200E-03	2.26667E-02	5.58575E+04
2	2.99200E-03	6.80000E-02	4.80821E+04
3	2.99200E-03	1.13333E-01	4.03067E+04
4	2.99200E-03	1.58667E-01	3.25312E+04
5	2.99200E-03	2.04000E-01	2.47558E+04
6	2.99200E-03	2.49333E-01	1.69803E+04
7	2.99200E-03	2.94667E-01	9.20488E+03
8	2.99200E-03	3.40000E-01	1.42943E+03
9	2.99200E-03	3.85333E-01	-6.34601E+03
10	5.50000E-02	4.19000E-01	-1.21204E+04

CASE   1 ANALYSIS
ELASTIC STRESSES AT X= 5.500

TRAJECTORY TIME STEP   1

J	AREA(SQ.IN)	Y(IN)	STRESS(PSI)
1	2.99200E-03	2.26667E-02	5.58575E+04
2	2.99200E-03	6.80000E-02	4.80821E+04
3	2.99200E-03	1.13333E-01	4.03067E+04
4	2.99200E-03	1.58667E-01	3.25312E+04
5	2.99200E-03	2.04000E-01	2.47558E+04
6	2.99200E-03	2.49333E-01	1.69803E+04
7	2.99200E-03	2.94667E-01	9.20488E+03
8	2.99200E-03	3.40000E-01	1.42943E+03
9	2.99200E-03	3.85333E-01	-6.34601E+03
10	5.50000E-02	4.19000E-01	-1.21204E+04

EXAMPLE PROBLEM 1 OUTPUT (Continued)

CREEP PREDICTION COMPUTER PROGRAM
TPSC EXAMPLE PROBLEM 1

RIB STIFFENED TPS PANEL

          SKIN GAGE = .022 INCHES
          RIB GAGE = .022 INCHES
          NUMBER OF RIBS = 3
          PITCH LENGTH = 1.000 INCHES
          PANEL EDGE LENGTH = .250 INCHES
          PANEL DEPTH = .430 INCHES
          CALCULATED MOMENT OF INERTIA = .0012046 IN**4
          ELASTIC NEUTRAL AXIS = .348 INCHES

PANEL LENGTH = 11.00 INCHES
PANEL WIDTH = 2.50 INCHES

APPLIED LOADS
          TWO POINT LOADS , DISTANCE FROM SUPPORT TO LOAD = 3.62 INCHES

TRAJECTORY DATA   •

     TIME (SECONDS)
     LOAD (LBS)
     TEMPERATURE (DEG F)

TIME		TOTAL LOAD	MIDSPAN SKIN TEMPERATURE
START	END		
0.00	20.00	114.145	825.0

CREEP PREDICTION COMPUTER PROGRAM

CYCLIC CREEP EQUATION DEFINITION

LN(STRAIN)= -2.62298E+01
            2.62485E+01 *(TEMP)
            4.68940E-01 *LN(TIME)
            1.40466E+00 *LN(STRESS)
            1.20000E-04 *(STRESS)**2

     WHERE   TIME = MINUTES
                 TEMPERATURE = DEG K/1000.
                 STRESS = KS1

CREEP PREDICTION COMPUTER PROGRAM
ELASTIC DEFLECTION SUMMARY

	BEAM STATION (INCHES)					
TIME(MIN)	.92	1.83	2.75	3.67	4.58	5.50
20.00	.0538	.1034	.1447	.1736	.1852	.1913

CREEP PREDICTION COMPUTER PROGRAM
FIRST CYCLE CREEP DEFLECTION SUMMARY

	BEAM STATION (INCHES)					
TIME	.92	1.83	2.75	3.67	4.58	5.50
20.00	.00874	.01718	.02468	.03020	.03249	.03373

B-67

EXAMPLE PROBLEM 1 OUTPUT (Continued)

CREEP PREDICTION COMPUTER PROGRAM

CREEP DEFLECTION SUMMARY

BEAM STATION (INCHES)

CYCLE	.92	1.83	2.75	3.67	4.58	5.50
1	.00874	.01718	.02468	.03020	.03249	.03373
3	.01460	.02869	.04121	.05042	.05425	.05631
10	.02542	.04995	.07174	.08776	.09443	.09801

CREEP PREDICTION COMPUTER PROGRAM

CREEP STRAINS (PERCENT)

CYCLE   1

BEAM STATION (INCHES)

HEIGHT	.92	1.83	2.75	3.67	4.58	5.50
.0227	.0019523	.0107827	.0266634	.0622175	.0694993	.0755903
.0680	.0017895	.0102664	.0259521	.0634048	.0699768	.0757375
.1133	.0016448	.0095076	.0243624	.0613660	.0674936	.0728482
.1587	.0014650	.0085030	.0219456	.0563412	.0618561	.0666706
.2040	.0012455	.0072417	.0187336	.0485964	.0533315	.0574367
.2493	.0009789	.0056934	.0147213	.0383663	.0420952	.0453565
.2947	.0006522	.0037995	.0098249	.0257351	.0282651	.0304843
.3400	.0002342	.0014010	.0036957	.0102425	.0113121	.0122585
.3853	-.0002450	-.0013657	-.0033317	-.0075228	-.0081952	-.0087799
.4190	-.0005176	-.0029499	-.0074319	-.0181604	-.0198653	-.0213520

CREEP PREDICTION COMPUTER PROGRAM

RESIDUAL STRESSES (PSI)

CYCLE   1

BEAM STATION (INCHES)

HEIGHT	.92	1.83	2.75	3.67	4.58	5.50
.0227	4.30E+01	2.73E+02	7.37E+02	2.25E+03	2.36E+03	2.51E+03
.0680	1.88E+01	1.17E+02	2.81E+02	7.87E+02	8.52E+02	9.20E+02
.1133	-1.51E+00	-8.48E+00	-7.08E+01	-2.98E+02	-3.10E+02	-3.09E+02
.1587	-1.76E+01	-1.06E+02	-3.24E+02	-1.03E+03	-1.10E+03	-1.15E+03
.2040	-2.90E+01	-1.70E+02	-4.83E+02	-1.44E+03	-1.54E+03	-1.63E+03
.2493	-3.47E+01	-2.02E+02	-5.46E+02	-1.55E+03	-1.67E+03	-1.78E+03
.2947	-3.31E+01	-1.91E+02	-5.04E+02	-1.38E+03	-1.49E+03	-1.59E+03
.3400	-2.06E+01	-1.21E+02	-3.15E+02	-8.65E+02	-9.44E+02	-1.01E+03
.3853	-7.54E-01	-6.79E+00	-1.96E+01	-8.42E+01	-9.30E+01	-1.01E+02
.4190	3.98E+00	2.19E+01	6.68E+01	1.93E+02	2.06E+02	2.16E+02

CREEP PREDICTION COMPUTER PROGRAM

CREEP STRAINS (PERCENT)

CYCLE   3

BEAM STATION (INCHES)

HEIGHT	.92	1.83	2.75	3.67	4.58	5.50
.0227	.0032486	.0185157	.0446756	.1050202	.1178299	.1274953
.0680	.0030056	.0173352	.0434295	.1053367	.1160093	.1258219
.1133	.0027497	.0160945	.0405599	.1009272	.1107138	.1196515
.1587	.0024793	.0143369	.0363911	.0920855	.1007887	.1086973
.2040	.0021322	.0121611	.0309542	.0790515	.0864245	.0931022
.2493	.0016475	.0096189	.0242208	.0620417	.0677946	.0729903
.2947	.0010933	.0063164	.0160737	.0413760	.0452280	.0487026
.3400	.0003863	.0022700	.0058898	.0158521	.0173473	.0186930
.3853	-.0004221	-.0024000	-.0058523	-.0136861	-.0150274	-.0162431
.4190	-.0008840	-.0050825	-.0127069	-.0313273	-.0343495	-.0370887

EXAMPLE PROBLEM 1 OUTPUT (Continued)

CREEP PREDICTION COMPUTER PROGRAM

RESIDUAL STRESSES (PSI)

CYCLE   3

BEAM STATION (INCHES)

HEIGHT	.92	1.83	2.75	3.67	4.58	5.50
.0227	6.72E+01	4.13E+02	1.25E+03	3.50E+03	3.69E+03	1.87E+03
.0680	3.27E+01	1.89E+02	4.47E+02	1.25E+03	1.36E+03	1.45E+03
.1133	-1.81E-01	-2.75E+01	-1.18E+02	-4.41E+02	-4.42E+02	-4.49E+02
.1587	-3.13E+01	-1.83E+02	-5.28E+02	-1.61E+03	-1.70E+03	-1.78E+03
.2040	-4.97E+01	-2.88E+02	-7.87E+02	-2.27E+03	-2.43E+03	-2.56E+03
.2493	-5.87E+01	-3.37E+02	-8.91E+02	-2.47E+03	-2.65E+03	-2.81E+03
.2947	-5.57E+01	-3.19E+02	-8.28E+02	-2.23E+03	-2.41E+03	-2.57E+03
.3400	-3.44E+01	-2.01E+02	-5.22E+02	-1.42E+03	-1.54E+03	-1.65E+03
.3853	-9.23E-01	-7.79E+00	-2.99E+01	-1.28E+02	-1.38E+02	-1.47E+02
.4190	7.31E+00	4.17E+01	1.13E+02	3.20E+02	3.44E+02	3.65E+02

CREEP PREDICTION COMPUTER PROGRAM

CREEP STRAINS (PERCENT)

CYCLE   10

BEAM STATION (INCHES)

HEIGHT	.92	1.83	2.75	3.67	4.58	5.50
.0227	.0057249	.0326460	.0801124	.1893706	.2104611	.2296524
.0680	.0052260	.0305254	.0766332	.1839271	.2027420	.2199245
.1133	.0049614	.0280929	.0705959	.1728558	.1895879	.2047676
.1587	.0043848	.0249140	.0629363	.1550245	.1704589	.1835790
.2040	.0036925	.0210548	.0532435	.1329808	.1450772	.1559563
.2493	.0028872	.0164199	.0415020	.1034762	.1131533	.1214909
.2947	.0018962	.0108849	.0274346	.0691145	.0755747	.0811269
.3400	.0006775	.0038824	.0100371	.0263652	.0287466	.0308543
.3853	-.0007372	-.0042896	-.0103624	-.0242349	-.0266806	-.0288725
.4190	-.0015571	-.0089320	-.0222741	-.0543836	-.0596371	-.0643824

CREEP PREDICTION COMPUTER PROGRAM

RESIDUAL STRESSES (PSI)

CYCLE   10

BEAM STATION (INCHES)

HEIGHT	.92	1.83	2.75	3.67	4.58	5.50
.0227	1.18E+02	7.02E+02	1.89E+03	5.25E+03	5.51E+03	5.73E+03
.0680	6.60E+01	3.15E+02	7.09E+02	2.05E+03	2.20E+03	2.31E+03
.1133	-1.44E+01	-3.47E+01	-1.60E+02	-4.90E+02	-4.72E+02	-4.57E+02
.1587	-5.48E+01	-2.95E+02	-8.33E+02	-2.33E+03	-2.43E+03	-2.52E+03
.2040	-8.62E+01	-4.75E+02	-1.27E+03	-3.46E+03	-3.66E+03	-3.82E+03
.2493	-1.02E+02	-5.61E+02	-1.46E+03	-3.86E+03	-4.10E+03	-4.31E+03
.2947	-9.42E+01	-5.40E+02	-1.37E+03	-3.61E+03	-3.88E+03	-4.11E+03
.3400	-6.04E+01	-3.44E+02	-8.88E+02	-2.37E+03	-2.57E+03	-2.74E+03
.3853	-2.61E+00	-7.80E+00	-5.13E+01	-2.22E+02	-2.35E+02	-2.49E+02
.4190	1.26E+01	7.13E+01	1.87E+02	4.94E+02	5.26E+02	5.54E+02

EXAMPLE PROBLEM 2

Example problem 2 demonstrates analysis for the 45.7 cm. long and 51.6 cm. wide beaded single skin corrugation stiffened panel shown in figure B-18(a). This panel is loaded with a uniform pressure and temperature where the pressure and temperature vary with time in each cycle as shown in figure B-18(c). The plate option is used in this problem and therefore the panel edge stiffness and Poisson's ratio are required input. The strain hardening theory of creep accumulation is applied in this example. SI units are used and the empirical creep equation is that for L605 (obtained in Phase I) as follows.

$$\ln\varepsilon = -2.89413 - .01743t + .54892 \ln t + 1.31015 \ln\sigma - 6.66548 \ (1/T)$$
$$+ .19131 \ln T + .00021(T\sigma t)$$

where t = time, hours
T = temperature, °K/1000
σ = stress, MPa

Deflection, strain, and stress output are requested after 1, 2, 3, 4 cycles and output are provided at 23 locations through the panel depth (NSECT + NBSECT) and 8 locations along the length (NSTAT).

Input and output for example problem 2 follows.

51.6 cm

X

simply supported
(typ. @ X = 0, X = 45.7)

45.7 cm

(a) PANEL GEOMETRY

p

X

45.7 cm

(b) PANEL LOAD

p, T

T

1 2 3 4 5

p
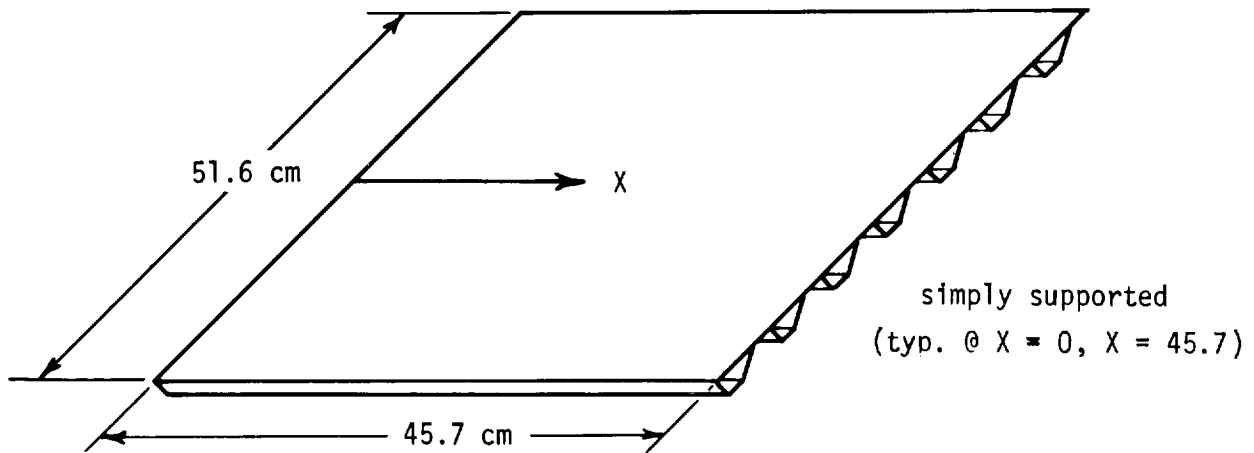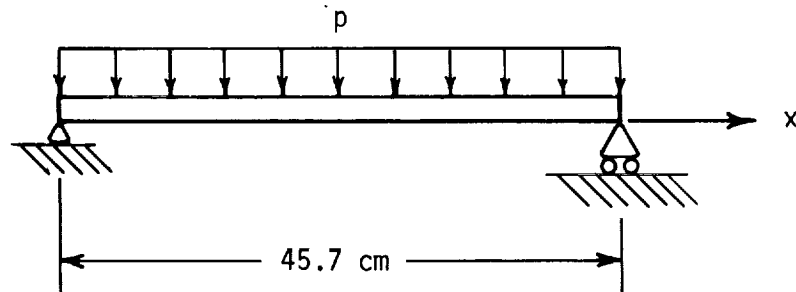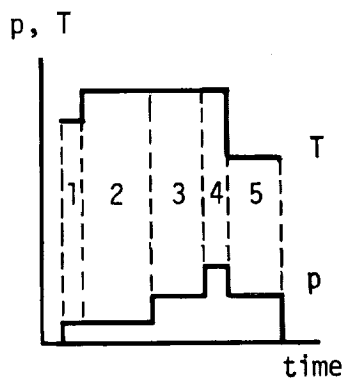
time

(c) TRAJECTORY

TRAJECTORY STEP	TIME (Min.)	TEMP (°K)	PRESSURE (Pa)
1	0-1.33	1122	758
2	1.33-4.67	1231	758
3	4.67-7.50	1231	1655
4	7.50-8.50	1225	2482
5	8.50-11.33	1014	1655

figure B-18 EXAMPLE PROBLEM 2

```
        NEWCAS=1,  $END
      Z(5)=-6.66546,Z(8)=.19131,Z(24)=.00021,
      Z(1)=-2.89414,Z(4)=-.01743,Z(6)=.54892,Z(7)=1.31015,
        TEMP(1)=1122.,1231.,1231.,1225.,1014.,
        DXTIME(1)=1.33,4.67,7.50,8.50,11.33,
        PRESS(1)= 758.,758.,1655.,2482.,1655.,
      NTIME=5,NCYCLE=4,NUMCYC=4,KCYCLE(1)=1,2,3,4,
      INDPLA=1,ESTIFF=.5078,XNU=.3,ECOEFF(1)=13.79E10,NTCON=0,
        INDBD=1,BRAD=-3.18,BDEP=.279,BWID=2.62,NBSECT=8,
      DEPTH=1.852,PITCH=3.63,EDGE=.36,FLAT=.711,PHICOR=12.63,
        PANWID=51.6,XLGTH=45.7,NCOR=14,TS=.0216,TC=.0140,
$CREEP INDGEO=2,        HARDOP=1.,TMAX=20.,NSTAT=8,SEC=15.,NSECT=15,
     TPSC EXAMPLE PROBLEM 2  TIME HARD
```

EXAMPLE PROBLEM 2 INPUT

PREDICTION OF CREEP IN
METALLIC TPS PANELS

PHASE III
SUMMARY REPORT
EXAMPLE PROBLEM 2 OUTPUT

NAS-1-11774

```
SCREEP
DEPTH   =   0.1852E+01,
PHICOR  =   0.1263E+02,
PITCH   =   0.363E+01,
FLAT    =   0.711E+00,
EDGE    =   0.36E+00,
NCOR    =   14,
TS      =   0.216E-01,
TC      =   0.14E-01,
XLGTH   =   0.457E+02,
TR      =   0.0,
NRIB    =   0,
RIBFLG  =   0.0,
ZPNE01  =   0.0,
ZPNE02  =   0.0,
NZEE    =   0,
TZEE    =   0.0,
ZEESF   =   0.0,
ZEESF1  =   0.0,
ZEEFF   =   0.0,
ZEEFF1  =   0.0,
BWID    =   0.262E+01,
BDEP    =   0.279E+00,
BPAD    =  -0.318E+01,
PRESS   =   0.758E+03,  0.758E+03,  0.1655E+04,  0.2482E+04,  0.1655E+04,  0.0,   0.0,   0.0,   0.0,   0.0,
TEMP    =   0.1122E+04,  0.1231E+04,  0.1231E+04,  0.1225E+04,  0.1014E+04,  0.0,   0.0,   0.0,   0.0,   0.0,
OXTIME  =   0.133E+01,  0.467E+01,  0.75E+01,  0.85E+01,  0.1133E+02,  0.0,   0.0,   0.0,   0.0,   0.0,
PLOAD   =   0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
ALEN    =   0.0,
XNU     =   0.3E+00,
PANWID  =   0.516E+02,
C       =   0.1E+01,  0.0,  0.0,  0.0,
D       =   0.1E+01,  0.0,  0.0,  0.0,
E       =   0.0, ...
```

```
NTIME   =   5,
XTEMP   =   0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
NEWCAS  =   2,
YTEMP   =   0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
EMOD    =   0.0,
```

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

EXAMPLE PROBLEM 2 OUTPUT

```
ETEMP    =  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,  0.0,
            0.0;  0.0;  0.0;  0.0;  0.0;  0.0;

INDGEO   =  2,

INDBD    =  1,

INDLOD   =  0,

INDSUP   =  0,

INDPLA   =  1,

INDTFL   =  0,

INDTFD   =  0,

KCYCLE   =  1,  2,  3,  4,  0,  0,  0,  0,  0,  0,

INDMOD   =  0,

INDELA   =  0,

NCYCLE   =  4,

NUMCYC   =  4,

ITCON    =  1,

NTCON    =  0,

ECOEFF   =  0.1379E+12,  0.0,  0.0,  0.0,

Z        = -0.289414E+01,  0.0,  0.0, -0.1743E-01, -0.666548E+01,  0.54892E+00,  0.131015E+01,  0.19131E+00,  0.0,  0.0,
            0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.21E-03,  0.0,  0.0,  0.0,  0.0,
            0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;
            0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;  0.0;

HARDOP   =  0.1E+01,

TMAX     =  0.2E+02,

INCYC    =  1,

ITIME    =  0,

IEQNTP   =  0,

IINTP    =  0,

IDIMEN   =  0,

ILOAD    =  0,

IEQNST   =  0,

NSTAT    =  8,

SEC      =  0.15E+02,

NSECT    =  15,

NRSECT   =  8,

IRESID   =  0,

RESSIN   =  0.0,  ...

ESTIFF   =  0.5078E+00,

INDD2    =  0,

INDSTR   =  0,

DETMO    =  0.0,

$END
```

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY · EAST

EXAMPLE PROBLEM 2 OUTPUT
CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 2.856

TRAJECTORY TIME STEP 1

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	7.16047E-01
2	6.03382E-02	8.90998E-02	6.66271E-01
3	6.03382E-02	2.39300E-01	5.75206E-01
4	6.03382E-02	3.89499E-01	4.84141E-01
5	6.03382E-02	5.39699E-01	3.93077E-01
6	6.03382E-02	6.89899E-01	3.02012E-01
7	6.03382E-02	8.40098E-01	2.10948E-01
8	6.03382E-02	9.90298E-01	1.19883E-01
9	6.03382E-02	1.14050E+00	2.88184E-02
10	6.03382E-02	1.29070E+00	-6.22462E-02
11	6.03382E-02	1.44090E+00	-1.53311E-01
12	6.03382E-02	1.59110E+00	-2.44375E-01
13	6.03382E-02	1.74130E+00	-3.35440E-01
14	1.49435E-01	1.82340E+00	-3.85216E-01
15	3.22271E-01	1.84120E+00	-3.96008E-01
16	1.63320E-01	1.78820E+00	-3.63879E-01
17	1.63320E-01	1.69826E+00	-3.09346E-01
18	1.63320E-01	1.63023E+00	-2.68099E-01
19	1.63320E-01	1.58460E+00	-2.40435E-01
20	1.63320E-01	1.56170E+00	-2.26552E-01

TRAJECTORY TIME STEP 2

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	7.16047E-01
2	6.03382E-02	8.90998E-02	6.66271E-01
3	6.03382E-02	2.39300E-01	5.75206E-01
4	6.03382E-02	3.89499E-01	4.84141E-01
5	6.03382E-02	5.39699E-01	3.93077E-01
6	6.03382E-02	6.89899E-01	3.02012E-01
7	6.03382E-02	8.40098E-01	2.10948E-01
8	6.03382E-02	9.90298E-01	1.19883E-01
9	6.03382E-02	1.14050E+00	2.88184E-02
10	6.03382E-02	1.29070E+00	-6.22462E-02
11	6.03382E-02	1.44090E+00	-1.53311E-01
12	6.03382E-02	1.59110E+00	-2.44375E-01
13	6.03382E-02	1.74130E+00	-3.35440E-01
14	1.49435E-01	1.82340E+00	-3.85216E-01
15	3.22271E-01	1.84120E+00	-3.96008E-01
16	1.63320E-01	1.78820E+00	-3.63879E-01
17	1.63320E-01	1.69826E+00	-3.09346E-01
18	1.63320E-01	1.63023E+00	-2.68099E-01
19	1.63320E-01	1.58460E+00	-2.40435E-01
20	1.63320E-01	1.56170E+00	-2.26552E-01

TRAJECTORY TIME STEP 3

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.56340E+00
2	6.03382E-02	8.90998E-02	1.45472E+00
3	6.03382E-02	2.39300E-01	1.25589E+00
4	6.03382E-02	3.89499E-01	1.05706E+00
5	6.03382E-02	5.39699E-01	8.58235E-01
6	6.03382E-02	6.89899E-01	6.59406E-01
7	6.03382E-02	8.40098E-01	4.60578E-01
8	6.03382E-02	9.90298E-01	2.61750E-01
9	6.03382E-02	1.14050E+00	6.29214E-02
10	6.03382E-02	1.29070E+00	-1.35907E-01
11	6.03382E-02	1.44090E+00	-3.34735E-01
12	6.03382E-02	1.59110E+00	-5.33564E-01
13	6.03382E-02	1.74130E+00	-7.32392E-01
14	1.49435E-01	1.82340E+00	-8.41073E-01
15	3.22271E-01	1.84120E+00	-8.64635E-01
16	1.63320E-01	1.78820E+00	-7.94485E-01
17	1.63320E-01	1.69826E+00	-6.75419E-01
18	1.63320E-01	1.63023E+00	-5.85361E-01
19	1.63320E-01	1.58460E+00	-5.24959E-01
20	1.63320E-01	1.56170E+00	-4.94649E-01

TRAJECTORY TIME STEP 4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	2.34463E+00
2	6.03382E-02	8.90998E-02	2.18164E+00
3	6.03382E-02	2.39300E-01	1.88346E+00
4	6.03382E-02	3.89499E-01	1.58528E+00
5	6.03382E-02	5.39699E-01	1.28709E+00
6	6.03382E-02	6.89899E-01	9.88911E-01
7	6.03382E-02	8.40098E-01	6.90728E-01
8	6.03382E-02	9.90298E-01	3.92546E-01
9	6.03382E-02	1.14050E+00	9.43631E-02
10	6.03382E-02	1.29070E+00	-2.03819E-01
11	6.03382E-02	1.44090E+00	-5.02002E-01
12	6.03382E-02	1.59110E+00	-8.00184E-01
13	6.03382E-02	1.74130E+00	-1.09837E+00
14	1.49435E-01	1.82340E+00	-1.26135E+00
15	3.22271E-01	1.84120E+00	-1.29669E+00
16	1.63320E-01	1.78820E+00	-1.19149E+00
17	1.63320E-01	1.69826E+00	-1.01293E+00
18	1.63320E-01	1.63023E+00	-8.77865E-01
19	1.63320E-01	1.58460E+00	-7.87280E-01
20	1.63320E-01	1.56170E+00	-7.41824E-01

B-75

EXAMPLE PROBLEM 2 OUTPUT

TRAJECTORY TIME STEP 5

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.56340E+00
2	6.03382E-02	8.90998E-02	1.45472E+00
3	6.03382E-02	2.39300E-01	1.25589E+00
4	6.03382E-02	3.89499E-01	1.05706E+00
5	6.03382E-02	5.39699E-01	8.56235E-01
6	6.03382E-02	6.89899E-01	6.59406E-01
7	6.03382E-02	8.40098E-01	4.60578E-01
8	6.03382E-02	9.90298E-01	2.61750E-01
9	6.03382E-02	1.14050E+00	6.29214E-02
10	6.03382E-02	1.29070E+00	-1.35907E-01
11	6.03382E-02	1.44090E+00	-3.34735E-01
12	6.03382E-02	1.59110E+00	-5.33564E-01
13	6.03382E-02	1.74130E+00	-7.32392E-01
14	1.49435E-01	1.82340E+00	-8.41073E-01
15	3.22271E-01	1.84120E+00	-8.64635E-01
16	1.63320E-01	1.78820E+00	-7.94485E-01
17	1.63320E-01	1.69826E+00	-6.75419E-01
18	1.63320E-01	1.63023E+00	-5.85361E-01
19	1.63320E-01	1.58460E+00	-5.24959E-01
20	1.63320E-01	1.56170E+00	-4.94649E-01

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 5.712

TRAJECTORY TIME STEP 1

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	2.00955E+00
2	6.03382E-02	8.90998E-02	1.86986E+00
3	6.03382E-02	2.39300E-01	1.61429E+00
4	6.03382E-02	3.89499E-01	1.35872E+00
5	6.03382E-02	5.39699E-01	1.10315E+00
6	6.03382E-02	6.89899E-01	8.47583E-01
7	6.03382E-02	8.40098E-01	5.92014E-01
8	6.03382E-02	9.90298E-01	3.36446E-01
9	6.03382E-02	1.14050E+00	8.08774E-02
10	6.03382E-02	1.29070E+00	-1.74691E-01
11	6.03382E-02	1.44090E+00	-4.30259E-01
12	6.03382E-02	1.59110E+00	-6.85828E-01
13	6.03382E-02	1.74130E+00	-9.41396E-01
14	1.49435E-01	1.82340E+00	-1.08109E+00
15	3.22271E-01	1.84120E+00	-1.11138E+00
16	1.63320E-01	1.78820E+00	-1.02121E+00
17	1.63320E-01	1.69826E+00	-8.68165E-01
18	1.63320E-01	1.63023E+00	-7.52407E-01
19	1.63320E-01	1.58460E+00	-6.74768E-01
20	1.63320E-01	1.56170E+00	-6.35808E-01

TRAJECTORY TIME STEP 2

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	2.00955E+00
2	6.03382E-02	8.90998E-02	1.86986E+00
3	6.03382E-02	2.39300E-01	1.61429E+00
4	6.03382E-02	3.89499E-01	1.35872E+00
5	6.03382E-02	5.39699E-01	1.10315E+00
6	6.03382E-02	6.89899E-01	8.47583E-01
7	6.03382E-02	8.40098E-01	5.92014E-01
8	6.03382E-02	9.90298E-01	3.36446E-01
9	6.03382E-02	1.14050E+00	8.08774E-02
10	6.03382E-02	1.29070E+00	-1.74691E-01
11	6.03382E-02	1.44090E+00	-4.30259E-01
12	6.03382E-02	1.59110E+00	-6.85828E-01
13	6.03382E-02	1.74130E+00	-9.41396E-01
14	1.49435E-01	1.82340E+00	-1.08109E+00
15	3.22271E-01	1.84120E+00	-1.11138E+00
16	1.63320E-01	1.78820E+00	-1.02121E+00
17	1.63320E-01	1.69826E+00	-8.68165E-01
18	1.63320E-01	1.63023E+00	-7.52407E-01
19	1.63320E-01	1.58460E+00	-6.74768E-01
20	1.63320E-01	1.56170E+00	-6.35808E-01

TRAJECTORY TIME STEP 3

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	4.38761E+00
2	6.03382E-02	8.90998E-02	4.08260E+00
3	6.03382E-02	2.39300E-01	3.52460E+00
4	6.03382E-02	3.89499E-01	2.96660E+00
5	6.03382E-02	5.39699E-01	2.40859E+00
6	6.03382E-02	6.89899E-01	1.85059E+00
7	6.03382E-02	8.40098E-01	1.29259E+00
8	6.03382E-02	9.90298E-01	7.34588E-01
9	6.03382E-02	1.14050E+00	1.76586E-01
10	6.03382E-02	1.29070E+00	-3.81416E-01
11	6.03382E-02	1.44090E+00	-9.39419E-01
12	6.03382E-02	1.59110E+00	-1.49742E+00
13	6.03382E-02	1.74130E+00	-2.05542E+00
14	1.49435E-01	1.82340E+00	-2.36043E+00
15	3.22271E-01	1.84120E+00	-2.42656E+00
16	1.63320E-01	1.78820E+00	-2.22968E+00
17	1.63320E-01	1.69826E+00	-1.89553E+00
18	1.63320E-01	1.63023E+00	-1.64279E+00
19	1.63320E-01	1.58460E+00	-1.47327E+00
20	1.63320E-01	1.56170E+00	-1.38821E+00

EXAMPLE PROBLEM 2 OUTPUT

TRAJECTORY TIME STEP 4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	6.58009E+00
2	6.03382E-02	8.90998E-02	6.12267E+00
3	6.03382E-02	2.39300E-01	5.28583E+00
4	6.03382E-02	3.89499E-01	4.44900E+00
5	6.03382E-02	5.39699E-01	3.61216E+00
6	6.03382E-02	6.89899E-01	2.77533E+00
7	6.03382E-02	8.40098E-01	1.93849E+00
8	6.03382E-02	9.90298E-01	1.10166E+00
9	6.03382E-02	1.14050E+00	2.64825E-01
10	6.03382E-02	1.29070E+00	-5.72009E-01
11	6.03382E-02	1.44090E+00	-1.40884E+00
12	6.03382E-02	1.59110E+00	-2.24566E+00
13	6.03382E-02	1.74130E+00	-3.08251E+00
14	1.49435E-01	1.82340E+00	-3.53993E+00
15	3.22271E-01	1.84120E+00	-3.63910E+00
16	1.63320E-01	1.78820E+00	-3.34385E+00
17	1.63320E-01	1.69826E+00	-2.84273E+00
18	1.63320E-01	1.63023E+00	-2.46369E+00
19	1.63320E-01	1.58460E+00	-2.20946E+00
20	1.63320E-01	1.56170E+00	-2.08189E+00

TRAJECTORY TIME STEP 5

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	4.38761E+00
2	6.03382E-02	8.90998E-02	4.08260E+00
3	6.03382E-02	2.39300E-01	3.52460E+00
4	6.03382E-02	3.89499E-01	2.96660E+00
5	6.03382E-02	5.39699E-01	2.40859E+00
6	6.03382E-02	6.89899E-01	1.85059E+00
7	6.03382E-02	8.40098E-01	1.29259E+00
8	6.03382E-02	9.90298E-01	7.34586E-01
9	6.03382E-02	1.14050E+00	1.76586E-01
10	6.03382E-02	1.29070E+00	-3.81416E-01
11	6.03382E-02	1.44090E+00	-9.39419E-01
12	6.03382E-02	1.59110E+00	-1.49742E+00
13	6.03382E-02	1.74130E+00	-2.05542E+00
14	1.49435E-01	1.82340E+00	-2.36043E+00
15	3.22271E-01	1.84120E+00	-2.42656E+00
16	1.63320E-01	1.78820E+00	-2.22968E+00
17	1.63320E-01	1.69826E+00	-1.89593E+00
18	1.63320E-01	1.63023E+00	-1.64279E+00
19	1.63320E-01	1.58460E+00	-1.47327E+00
20	1.63320E-01	1.56170E+00	-1.38821E+00

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 8.569

TRAJECTORY TIME STEP 1

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	3.11827E+00
2	6.03382E-02	8.90998E-02	2.90150E+00
3	6.03382E-02	2.39300E-01	2.50493E+00
4	6.03382E-02	3.89499E-01	2.10836E+00
5	6.03382E-02	5.39699E-01	1.71179E+00
6	6.03382E-02	6.89899E-01	1.31521E+00
7	6.03382E-02	8.40098E-01	9.18643E-01
8	6.03382E-02	9.90298E-01	5.22071E-01
9	6.03382E-02	1.14050E+00	1.25499E-01
10	6.03382E-02	1.29070E+00	-2.71072E-01
11	6.03382E-02	1.44090E+00	-6.67644E-01
12	6.03382E-02	1.59110E+00	-1.06422E+00
13	6.03382E-02	1.74130E+00	-1.46079E+00
14	1.49435E-01	1.82340E+00	-1.67755E+00
15	3.22271E-01	1.84120E+00	-1.72455E+00
16	1.63320E-01	1.78820E+00	-1.58463E+00
17	1.63320E-01	1.69826E+00	-1.34715E+00
18	1.63320E-01	1.63023E+00	-1.16753E+00
19	1.63320E-01	1.58460E+00	-1.04705E+00
20	1.63320E-01	1.56170E+00	-9.86599E-01

TRAJECTORY TIME STEP 2

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	3.11827E+00
2	6.03382E-02	8.90998E-02	2.90150E+00
3	6.03382E-02	2.39300E-01	2.50493E+00
4	6.03382E-02	3.89499E-01	2.10836E+00
5	6.03382E-02	5.39699E-01	1.71179E+00
6	6.03382E-02	6.89899E-01	1.31521E+00
7	6.03382E-02	8.40098E-01	9.18643E-01
8	6.03382E-02	9.90298E-01	5.22071E-01
9	6.03382E-02	1.14050E+00	1.25499E-01
10	6.03382E-02	1.29070E+00	-2.71072E-01
11	6.03382E-02	1.44090E+00	-6.67644E-01
12	6.03382E-02	1.59110E+00	-1.06422E+00
13	6.03382E-02	1.74130E+00	-1.46079E+00
14	1.49435E-01	1.82340E+00	-1.67755E+00
15	3.22271E-01	1.84120E+00	-1.72455E+00
16	1.63320E-01	1.78820E+00	-1.58463E+00
17	1.63320E-01	1.69826E+00	-1.34715E+00
18	1.63320E-01	1.63023E+00	-1.16753E+00
19	1.63320E-01	1.58460E+00	-1.04705E+00
20	1.63320E-01	1.56170E+00	-9.86599E-01

EXAMPLE PROBLEM 2 OUTPUT

TRAJECTORY TIME STEP 3

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	6.80836E+00
2	6.03382E-02	8.90998E-02	6.33507E+00
3	6.03382E-02	2.39300E-01	5.46921E+00
4	6.03382E-02	3.89499E-01	4.60334E+00
5	6.03382E-02	5.39699E-01	3.73747E+00
6	6.03382E-02	6.89899E-01	2.87161E+00
7	6.03382E-02	8.40098E-01	2.00574E+00
8	6.03382E-02	9.90298E-01	1.13988E+00
9	6.03382E-02	1.14050E+00	2.74013E-01
10	6.03382E-02	1.29070E+00	-5.91853E-01
11	6.03382E-02	1.44090E+00	-1.45772E+00
12	6.03382E-02	1.59110E+00	-2.32358E+00
13	6.03382E-02	1.74130E+00	-3.18945E+00
14	1.49435E-01	1.82340E+00	-3.66274E+00
15	3.22271E-01	1.84120E+00	-3.76535E+00
16	1.63320E-01	1.78820E+00	-3.45985E+00
17	1.63320E-01	1.69826E+00	-2.94134E+00
18	1.63320E-01	1.63023E+00	-2.54915E+00
19	1.63320E-01	1.58460E+00	-2.28611E+00
20	1.63320E-01	1.56170E+00	-2.15412E+00

TRAJECTORY TIME STEP 4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.02105E+01
2	6.03382E-02	8.90998E-02	9.50060E+00
3	6.03382E-02	2.39300E-01	8.20216E+00
4	6.03382E-02	3.89499E-01	6.90352E+00
5	6.03382E-02	5.39699E-01	5.60508E+00
6	6.03382E-02	6.89899E-01	4.30655E+00
7	6.03382E-02	8.40098E-01	3.00801E+00
8	6.03382E-02	9.90298E-01	1.70947E+00
9	6.03382E-02	1.14050E+00	4.10936E-01
10	6.03382E-02	1.29070E+00	-8.87601E-01
11	6.03382E-02	1.44090E+00	-2.18614E+00
12	6.03382E-02	1.59110E+00	-3.48467E+00
13	6.03382E-02	1.74130E+00	-4.78321E+00
14	1.49435E-01	1.82340E+00	-5.49300E+00
15	3.22271E-01	1.84120E+00	-5.64688E+00
16	1.63320E-01	1.78820E+00	-5.18874E+00
17	1.63320E-01	1.69826E+00	-4.41113E+00
18	1.63320E-01	1.63023E+00	-3.82296E+00
19	1.63320E-01	1.58460E+00	-3.43848E+00
20	1.63320E-01	1.56170E+00	-3.23053E+00

TRAJECTORY TIME STEP 5

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	6.80836E+00
2	6.03382E-02	8.90998E-02	6.33507E+00
3	6.03382E-02	2.39300E-01	5.46921E+00
4	6.03382E-02	3.89499E-01	4.60334E+00
5	6.03382E-02	5.39699E-01	3.73747E+00
6	6.03382E-02	6.89899E-01	2.87161E+00
7	6.03382E-02	8.40098E-01	2.00574E+00
8	6.03382E-02	9.90298E-01	1.13988E+00
9	6.03382E-02	1.14050E+00	2.74013E-01
10	6.03382E-02	1.29070E+00	-5.91853E-01
11	6.03382E-02	1.44090E+00	-1.45772E+00
12	6.03382E-02	1.59110E+00	-2.32358E+00
13	6.03382E-02	1.74130E+00	-3.18945E+00
14	1.49435E-01	1.82340E+00	-3.66274E+00
15	3.22271E-01	1.84120E+00	-3.76535E+00
16	1.63320E-01	1.78820E+00	-3.45985E+00
17	1.63320E-01	1.69826E+00	-2.94134E+00
18	1.63320E-01	1.63023E+00	-2.54915E+00
19	1.63320E-01	1.58460E+00	-2.28611E+00
20	1.63320E-01	1.56170E+00	-2.15412E+00

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 11.425

TRAJECTORY TIME STEP 1

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	4.04220E+00
2	6.03382E-02	8.90998E-02	3.76120E+00
3	6.03382E-02	2.39300E-01	3.24713E+00
4	6.03382E-02	3.89499E-01	2.73306E+00
5	6.03382E-02	5.39699E-01	2.21898E+00
6	6.03382E-02	6.89899E-01	1.70491E+00
7	6.03382E-02	8.40098E-01	1.19083E+00
8	6.03382E-02	9.90298E-01	6.76759E-01
9	6.03382E-02	1.14050E+00	1.62684E-01
10	6.03382E-02	1.29070E+00	-3.51390E-01
11	6.03382E-02	1.44090E+00	-8.65464E-01
12	6.03382E-02	1.59110E+00	-1.37954E+00
13	6.03382E-02	1.74130E+00	-1.89361E+00
14	1.49435E-01	1.82340E+00	-2.17461E+00
15	3.22271E-01	1.84120E+00	-2.23553E+00
16	1.63320E-01	1.78820E+00	-2.05416E+00
17	1.63320E-01	1.69826E+00	-1.74631E+00
18	1.63320E-01	1.63023E+00	-1.51346E+00
19	1.63320E-01	1.58460E+00	-1.35729E+00
20	1.63320E-01	1.56170E+00	-1.27892E+00

EXAMPLE PROBLEM 2 OUTPUT

TRAJECTORY TIME STEP 2

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	4.04220E+00
2	6.03382E-02	8.90998E-02	3.76120E+00
3	6.03382E-02	2.39300E-01	3.24713E+00
4	6.03382E-02	3.89499E-01	2.73306E+00
5	6.03382E-02	5.39699E-01	2.21898E+00
6	6.03382E-02	6.89899E-01	1.70491E+00
7	6.03382E-02	8.40338E-01	1.19083E+00
8	6.03382E-02	9.90298E-01	6.76759E-01
9	6.03382E-02	1.14050E+00	1.62684E-01
10	6.03382E-02	1.29070E+00	-3.51390E-01
11	6.03382E-02	1.44090E+00	-8.65464E-01
12	6.03382E-02	1.59110E+00	-1.37954E+00
13	6.03382E-02	1.74130E+00	-1.89361E+00
14	1.49435E-01	1.82340E+00	-2.17461E+00
15	3.22271E-01	1.84120E+00	-2.23553E+00
16	1.63320E-01	1.78820E+00	-2.05416E+00
17	1.63320E-01	1.69826E+00	-1.74631E+00
18	1.63320E-01	1.63023E+00	-1.51346E+00
19	1.63320E-01	1.58460E+00	-1.35729E+00
20	1.63320E-01	1.56170E+00	-1.27892E+00

TRAJECTORY TIME STEP 3

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	8.82565E+00
2	6.03382E-02	8.90998E-02	8.21213E+00
3	6.03382E-02	2.39300E-01	7.08971E+00
4	6.03382E-02	3.89499E-01	5.96729E+00
5	6.03382E-02	5.39699E-01	4.84487E+00
6	6.03382E-02	6.89899E-01	3.72246E+00
7	6.03382E-02	8.40098E-01	2.60004E+00
8	6.03382E-02	9.90298E-01	1.47762E+00
9	6.03382E-02	1.14050E+00	3.55201E-01
10	6.03382E-02	1.29070E+00	-7.67217E-01
11	6.03382E-02	1.44090E+00	-1.88964E+00
12	6.03382E-02	1.59110E+00	-3.01205E+00
13	6.03382E-02	1.74130E+00	-4.13447E+00
14	1.49435E-01	1.82340E+00	-4.74799E+00
15	3.22271E-01	1.84120E+00	-4.88101E+00
16	1.63320E-01	1.78820E+00	-4.48500E+00
17	1.63320E-01	1.69826E+00	-3.81285E+00
18	1.63320E-01	1.63023E+00	-3.30446E+00
19	1.63320E-01	1.58460E+00	-2.96348E+00
20	1.63320E-01	1.56170E+00	-2.79237E+00

TRAJECTORY TIME STEP 4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.32358E+01
2	6.03382E-02	8.90998E-02	1.23157E+01
3	6.03382E-02	2.39300E-01	1.06324E+01
4	6.03382E-02	3.89499E-01	8.94914E+00
5	6.03382E-02	5.39699E-01	7.26585E+00
6	6.03382E-02	6.89899E-01	5.58256E+00
7	6.03382E-02	8.40098E-01	3.89927E+00
8	6.03382E-02	9.90298E-01	2.21598E+00
9	6.03382E-02	1.14050E+00	5.32695E-01
10	6.03382E-02	1.29070E+00	-1.15059E+00
11	6.03382E-02	1.44090E+00	-2.83388E+00
12	6.03382E-02	1.59110E+00	-4.51717E+00
13	6.03382E-02	1.74130E+00	-6.20046E+00
14	1.49435E-01	1.82340E+00	-7.12055E+00
15	3.22271E-01	1.84120E+00	-7.32004E+00
16	1.63320E-01	1.78820E+00	-6.72614E+00
17	1.63320E-01	1.69826E+00	-5.71813E+00
18	1.63320E-01	1.63023E+00	-4.95569E+00
19	1.63320E-01	1.58460E+00	-4.44432E+00
20	1.63320E-01	1.56170E+00	-4.18772E+00

TRAJECTORY TIME STEP 5

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	8.82565E+00
2	6.03382E-02	8.90998E-02	8.21213E+00
3	6.03382E-02	2.39300E-01	7.08971E+00
4	6.03382E-02	3.89499E-01	5.96729E+00
5	6.03382E-02	5.39699E-01	4.84487E+00
6	6.03382E-02	6.89899E-01	3.72246E+00
7	6.03382E-02	8.40098E-01	2.60004E+00
8	6.03382E-02	9.90298E-01	1.47762E+00
9	6.03382E-02	1.14050E+00	3.55201E-01
10	6.03382E-02	1.29070E+00	-7.67217E-01
11	6.03382E-02	1.44090E+00	-1.88964E+00
12	6.03382E-02	1.59110E+00	-3.01205E+00
13	6.03382E-02	1.74130E+00	-4.13447E+00
14	1.49435E-01	1.82340E+00	-4.74799E+00
15	3.22271E-01	1.84120E+00	-4.88101E+00
16	1.63320E-01	1.78820E+00	-4.48500E+00
17	1.63320E-01	1.69826E+00	-3.81285E+00
18	1.63320E-01	1.63023E+00	-3.30446E+00
19	1.63320E-01	1.58460E+00	-2.96348E+00
20	1.63320E-01	1.56170E+00	-2.79237E+00

EXAMPLE PROBLEM 2 OUTPUT
CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 14.281

TRAJECTORY TIME STEP 1

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	4.78135E+00
2	6.03382E-02	8.90998E-02	4.44897E+00
3	6.03382E-02	2.39300E-01	3.84089E+00
4	6.03382E-02	3.89499E-01	3.23281E+00
5	6.03382E-02	5.39699E-01	2.62474E+00
6	6.03382E-02	6.89899E-01	2.01666E+00
7	6.03382E-02	8.40098E-01	1.40859E+00
8	6.03382E-02	9.90298E-01	8.00509E-01
9	6.03382E-02	1.14050E+00	1.92432E-01
10	6.03382E-02	1.29070E+00	-4.15644E-01
11	6.03382E-02	1.44090E+00	-1.02372E+00
12	6.03382E-02	1.59110E+00	-1.63180E+00
13	6.03382E-02	1.74130E+00	-2.23987E+00
14	1.49435E-01	1.82340E+00	-2.57225E+00
15	3.22271E-01	1.84120E+00	-2.64431E+00
16	1.63320E-01	1.78820E+00	-2.42977E+00
17	1.63320E-01	1.69826E+00	-2.06563E+00
18	1.63320E-01	1.63023E+00	-1.79021E+00
19	1.63320E-01	1.58460E+00	-1.60548E+00
20	1.63320E-01	1.56170E+00	-1.51272E+00

TRAJECTORY TIME STEP 2

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	4.78135E+00
2	6.03382E-02	8.90938E-02	4.44897E+00
3	6.03382E-02	2.39300E-01	3.84089E+00
4	6.03382E-02	3.89499E-01	3.23281E+00
5	6.03382E-02	5.39699E-01	2.62474E+00
6	6.03382E-02	6.89899E-01	2.01666E+00
7	6.03382E-02	8.40098E-01	1.40859E+00
8	6.03382E-02	9.90298E-01	8.00509E-01
9	6.03382E-02	1.14050E+00	1.92432E-01
10	6.03382E-02	1.29070E+00	-4.15644E-01
11	6.03382E-02	1.44090E+00	-1.02372E+00
12	6.03382E-02	1.59110E+00	-1.63180E+00
13	6.03382E-02	1.74130E+00	-2.23987E+00
14	1.49435E-01	1.82340E+00	-2.57225E+00
15	3.22271E-01	1.84120E+00	-2.64431E+00
16	1.63320E-01	1.78820E+00	-2.42977E+00
17	1.63320E-01	1.69826E+00	-2.06563E+00
18	1.63320E-01	1.63023E+00	-1.79021E+00
19	1.63320E-01	1.58460E+00	-1.60548E+00
20	1.63320E-01	1.56170E+00	-1.51278E+00

TRAJECTORY TIME STEP 3

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.04395E+01
2	6.03382E-02	8.90938E-02	9.71378E+00
3	6.03382E-02	2.39300E-01	8.38611E+00
4	6.03382E-02	3.89499E-01	7.05845E+00
5	6.03382E-02	5.39699E-01	5.73079E+00
6	6.03382E-02	6.89899E-01	4.40313E+00
7	6.03382E-02	8.40098E-01	3.07547E+00
8	6.03382E-02	9.90298E-01	1.74781E+00
9	6.03382E-02	1.14050E+00	4.20153E-01
10	6.03382E-02	1.29070E+00	-9.07508E-01
11	6.03382E-02	1.44090E+00	-2.23517E+00
12	6.03382E-02	1.59110E+00	-3.56283E+00
13	6.03382E-02	1.74130E+00	-4.89049E+00
14	1.49435E-01	1.82340E+00	-5.61619E+00
15	3.22271E-01	1.84120E+00	-5.77353E+00
16	1.63320E-01	1.78820E+00	-5.30511E+00
17	1.63320E-01	1.69826E+00	-4.51006E+00
18	1.63320E-01	1.63023E+00	-3.90872E+00
19	1.63320E-01	1.58460E+00	-3.50537E+00
20	1.63320E-01	1.56170E+00	-3.30298E+00

TRAJECTORY TIME STEP 4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.56561E+01
2	6.03382E-02	8.90998E-02	1.45677E+01
3	6.03382E-02	2.39300E-01	1.25766E+01
4	6.03382E-02	3.89499E-01	1.05855E+01
5	6.03382E-02	5.39699E-01	8.59446E+00
6	6.03382E-02	6.89899E-01	6.60337E+00
7	6.03382E-02	8.40098E-01	4.61228E+00
8	6.03382E-02	9.90298E-01	2.62119E+00
9	6.03382E-02	1.14050E+00	6.30102E-01
10	6.03382E-02	1.29070E+00	-1.36099E+00
11	6.03382E-02	1.44090E+00	-3.35208E+00
12	6.03382E-02	1.59110E+00	-5.34317E+00
13	6.03382E-02	1.74130E+00	-7.33426E+00
14	1.49435E-01	1.82340E+00	-8.42259E+00
15	3.22271E-01	1.84120E+00	-8.65856E+00
16	1.63320E-01	1.78820E+00	-7.95606E+00
17	1.63320E-01	1.69826E+00	-6.76373E+00
18	1.63320E-01	1.63023E+00	-5.86187E+00
19	1.63320E-01	1.58460E+00	-5.25700E+00
20	1.63320E-01	1.56170E+00	-4.95347E+00

EXAMPLE PROBLEM 2 OUTPUT

TRAJECTORY TIME STEP 5

J	AREA (SO.CM)	Y(CM)	STRESS (MPA)
1	4.12574E-01	6.99999E-03	1.04395E+01
2	6.03382E-02	8.90998E-02	9.71378E+00
3	6.03382E-02	2.39300E-01	8.38611E+00
4	6.03382E-02	3.89499E-01	7.05845E+00
5	6.03382E-02	5.39699E-01	5.73079E+00
6	6.03382E-02	6.89899E-01	4.40313E+00
7	6.03382E-02	8.40098E-01	3.07547E+00
8	6.03382E-02	9.90298E-01	1.74781E+00
9	6.03382E-02	1.14050E+00	4.20193E-01
10	6.03382E-02	1.29070E+00	-9.07508E-01
11	6.03382E-02	1.44090E+00	-2.23517E+00
12	6.03382E-02	1.59110E+00	-3.56283E+00
13	6.03382E-02	1.74130E+00	-4.89049E+00
14	1.49435E-01	1.82340E+00	-5.61619E+00
15	3.22271E-01	1.84120E+00	-5.77353E+00
16	1.63320E-01	1.78820E+00	-5.30511E+00
17	1.63320E-01	1.69826E+00	-4.51006E+00
18	1.63320E-01	1.63023E+00	-3.90870E+00
19	1.63320E-01	1.58460E+00	-3.50537E+00
20	1.63320E-01	1.56170E+00	-3.30298E+00

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 17.137

TRAJECTORY TIME STEP 1

J	AREA (SO.CM)	Y(CM)	STRESS (MPA)
1	4.12574E-01	6.99999E-03	5.33570E+00
2	6.03382E-02	8.90998E-02	4.96479E+00
3	6.03382E-02	2.39300E-01	4.28621E+00
4	6.03382E-02	3.89499E-01	3.60763E+00
5	6.03382E-02	5.39699E-01	2.92906E+00
6	6.03382E-02	6.89899E-01	2.25048E+00
7	6.03382E-02	8.40098E-01	1.57190E+00
8	6.03382E-02	9.90298E-01	8.93322E-01
9	6.03382E-02	1.14050E+00	2.14743E-01
10	6.03382E-02	1.29070E+00	-4.63835E-01
11	6.03382E-02	1.44090E+00	-1.14241E+00
12	6.03382E-02	1.59110E+00	-1.82099E+00
13	6.03382E-02	1.74130E+00	-2.49957E+00
14	1.49435E-01	1.82340E+00	-2.87048E+00
15	3.22271E-01	1.84120E+00	-2.95090E+00
16	1.63320E-01	1.78820E+00	-2.71149E+00
17	1.63320E-01	1.69826E+00	-2.30513E+00
18	1.63320E-01	1.63023E+00	-1.99777E+00
19	1.63320E-01	1.58460E+00	-1.79163E+00
20	1.63320E-01	1.56170E+00	-1.68818E+00

TRAJECTORY TIME STEP 2

J	AREA (SO.CM)	Y(CM)	STRESS (MPA)
1	4.12574E-01	6.99999E-03	5.33570E+00
2	6.03382E-02	8.90998E-02	4.96479E+00
3	6.03382E-02	2.39300E-01	4.28621E+00
4	6.03382E-02	3.89499E-01	3.60763E+00
5	6.03382E-02	5.39699E-01	2.92906E+00
6	6.03382E-02	6.89899E-01	2.25048E+00
7	6.03382E-02	8.40098E-01	1.57190E+00
8	6.03382E-02	9.90298E-01	8.93322E-01
9	6.03382E-02	1.14050E+00	2.14743E-01
10	6.03382E-02	1.29070E+00	-4.63835E-01
11	6.03382E-02	1.44090E+00	-1.14241E+00
12	6.03382E-02	1.59110E+00	-1.82099E+00
13	6.03382E-02	1.74130E+00	-2.49957E+00
14	1.49435E-01	1.82340E+00	-2.87048E+00
15	3.22271E-01	1.84120E+00	-2.95090E+00
16	1.63320E-01	1.78820E+00	-2.71149E+00
17	1.63320E-01	1.69826E+00	-2.30513E+00
18	1.63320E-01	1.63023E+00	-1.99777E+00
19	1.63320E-01	1.58460E+00	-1.79163E+00
20	1.63320E-01	1.56170E+00	-1.68818E+00

TRAJECTORY TIME STEP 3

J	AREA (SO.CM)	Y(CM)	STRESS (MPA)
1	4.12574E-01	6.99999E-03	1.16499E+01
2	6.03382E-02	8.90998E-02	1.08400E+01
3	6.03382E-02	2.39300E-01	9.35042E+00
4	6.03382E-02	3.89499E-01	7.87683E+00
5	6.03382E-02	5.39699E-01	6.39521E+00
6	6.03382E-02	6.89899E-01	4.91364E+00
7	6.03382E-02	8.40098E-01	3.43205E+00
8	6.03382E-02	9.90298E-01	1.95046E+00
9	6.03382E-02	1.14050E+00	4.68866E-01
10	6.03382E-02	1.29070E+00	-1.01273E+00
11	6.03382E-02	1.44090E+00	-2.49432E+00
12	6.03382E-02	1.59110E+00	-3.97591E+00
13	6.03382E-02	1.74130E+00	-5.45750E+00
14	1.49435E-01	1.82340E+00	-6.26735E+00
15	3.22271E-01	1.84120E+00	-6.44293E+00
16	1.63320E-01	1.78820E+00	-5.92019E+00
17	1.63320E-01	1.69826E+00	-5.03296E+00
18	1.63320E-01	1.63023E+00	-4.36188E+00
19	1.63320E-01	1.58460E+00	-3.91179E+00
20	1.63320E-01	1.56170E+00	-3.68593E+00

EXAMPLE PROBLEM 2 OUTPUT
TRAJECTORY TIME STEP 4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.74713E+01
2	6.03382E-02	8.90998E-02	1.62567E+01
3	6.03382E-02	2.39300E-01	1.40348E+01
4	6.03382E-02	3.89499E-01	1.18129E+01
5	6.03382E-02	5.39699E-01	9.59092E+00
6	6.03382E-02	6.89899E-01	7.36898E+00
7	6.03382E-02	8.40098E-01	5.14704E+00
8	6.03382E-02	9.90298E-01	2.92513E+00
9	6.03382E-02	1.14050E+00	7.03157E-01
10	6.03382E-02	1.29070E+00	-1.51874E+00
11	6.03382E-02	1.44090E+00	-3.74072E+00
12	6.03382E-02	1.59110E+00	-5.96266E+00
13	6.03382E-02	1.74130E+00	-8.18460E+00
14	1.49435E-01	1.82340E+00	-9.39913E+00
15	3.22271E-01	1.84120E+00	-9.65245E+00
16	1.63320E-01	1.78820E+00	-8.87850E+00
17	1.63320E-01	1.69826E+00	-7.54793E+00
18	1.63320E-01	1.63023E+00	-6.54151E+00
19	1.63320E-01	1.58460E+00	-5.86651E+00
20	1.63320E-01	1.56170E+00	-5.52779E+00

TRAJECTORY TIME STEP 5

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.16499E+01
2	6.03382E-02	8.90998E-02	1.08400E+01
3	6.03382E-02	2.39300E-01	9.35842E+00
4	6.03382E-02	3.89499E-01	7.87683E+00
5	6.03382E-02	5.39699E-01	6.39523E+00
6	6.03382E-02	6.89899E-01	4.91364E+00
7	6.03382E-02	8.40098E-01	3.43205E+00
8	6.03382E-02	9.90298E-01	1.95046E+00
9	6.03382E-02	1.14050E+00	4.68866E-01
10	6.03382E-02	1.29070E+00	-1.01273E+00
11	6.03382E-02	1.44090E+00	-2.49432E+00
12	6.03382E-02	1.59110E+00	-3.97591E+00
13	6.03385E-02	1.74130E+00	-5.45750E+00
14	1.49435E-01	1.82340E+00	-6.26735E+00
15	3.22271E-01	1.84120E+00	-6.44293E+00
16	1.63320E-01	1.78820E+00	-5.92019E+00
17	1.63320E-01	1.69826E+00	-5.03296E+00
18	1.63320E-01	1.63023E+00	-4.36188E+00
19	1.63320E-01	1.58460E+00	-3.91179E+00
20	1.63320E-01	1.56170E+00	-3.68593E+00

CASE 1 ANALYSIS
ELASTIC STRESSES AT X= 19.994

TRAJECTORY TIME STEP 1

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	5.70528E+00
2	6.03382E-02	8.90998E-02	5.30867E+00
3	6.03382E-02	2.39300E-01	4.58309E+00
4	6.03382E-02	3.89499E-01	3.85751E+00
5	6.03382E-02	5.39699E-01	3.13193E+00
6	6.03382E-02	6.89899E-01	2.40635E+00
7	6.03382E-02	8.40098E-01	1.68078E+00
8	6.03382E-02	9.90298E-01	9.55197E-01
9	6.03382E-02	1.14050E+00	2.29617E-01
10	6.03382E-02	1.29070E+00	-4.95962E-01
11	6.03382E-02	1.44090E+00	-1.22154E+00
12	6.03382E-02	1.59110E+00	-1.94712E+00
13	6.03382E-02	1.74130E+00	-2.67270E+00
14	1.49435E-01	1.82340E+00	-3.06930E+00
15	3.22271E-01	1.84120E+00	-3.15529E+00
16	1.63320E-01	1.78820E+00	-2.89929E+00
17	1.63320E-01	1.69826E+00	-2.46479E+00
18	1.63320E-01	1.63023E+00	-2.13614E+00
19	1.63320E-01	1.58460E+00	-1.91572E+00
20	1.63320E-01	1.56170E+00	-1.80511E+00

TRAJECTORY TIME STEP 2

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	5.70528E+00
2	6.03382E-02	8.90998E-02	5.30867E+00
3	6.03382E-02	2.39300E-01	4.58309E+00
4	6.03382E-02	3.89499E-01	3.85751E+00
5	6.03382E-02	5.39699E-01	3.13193E+00
6	6.03382E-02	6.89899E-01	2.40635E+00
7	6.03382E-02	8.40098E-01	1.68078E+00
8	6.03382E-02	9.90298E-01	9.55197E-01
9	6.03382E-02	1.14050E+00	2.29617E-01
10	6.03382E-02	1.29070E+00	-4.95962E-01
11	6.03382E-02	1.44090E+00	-1.22154E+00
12	6.03382E-02	1.59110E+00	-1.94712E+00
13	6.03382E-02	1.74130E+00	-2.67270E+00
14	1.49435E-01	1.82340E+00	-3.06930E+00
15	3.22271E-01	1.84120E+00	-3.15529E+00
16	1.63320E-01	1.78820E+00	-2.89929E+00
17	1.63320E-01	1.69826E+00	-2.46479E+00
18	1.63320E-01	1.63023E+00	-2.13614E+00
19	1.63320E-01	1.58460E+00	-1.91572E+00
20	1.63320E-01	1.56170E+00	-1.80511E+00

EXAMPLE PROBLEM 2 OUTPUT

TRAJECTORY TIME STEP   3

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.24568E+01
2	6.03382E-02	8.90999E-02	1.15908E+01
3	6.03382E-02	2.39300E-01	1.00066E+01
4	6.03382E-02	3.89499E-01	8.42241E+00
5	6.03382E-02	5.39699E-01	6.83819E+00
6	6.03382E-02	6.89899E-01	5.25398E+00
7	6.03382E-02	8.40098E-01	3.65677E+00
8	6.03382E-02	9.90298E-01	2.08555E+00
9	6.03382E-02	1.14050E+00	5.01341E-01
10	6.03382E-02	1.29070E+00	-1.08287E+00
11	6.03382E-02	1.44090E+00	-2.66708E+00
12	6.03382E-02	1.59110E+00	-4.25130E+00
13	6.03382E-02	1.74130E+00	-5.83551E+00
14	1.49435E-01	1.82340E+00	-6.70145E+00
15	3.22271E-01	1.84120E+00	-6.88919E+00
16	1.63320E-01	1.78820E+00	-6.33025E+00
17	1.63320E-01	1.69826E+00	-5.38157E+00
18	1.63320E-01	1.63023E+00	-4.66401E+00
19	1.63320E-01	1.58460E+00	-4.18274E+00
20	1.63320E-01	1.56170E+00	-3.94124E+00

TRAJECTORY TIME STEP   4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.86814E+01
2	6.03382E-02	8.90998E-02	1.73827E+01
3	6.03382E-02	2.39300E-01	1.50069E+01
4	6.03382E-02	3.89499E-01	1.26311E+01
5	6.03382E-02	5.39699E-01	1.02552E+01
6	6.03382E-02	6.89899E-01	7.87938E+00
7	6.03382E-02	8.40098E-01	5.50354E+00
8	6.03382E-02	9.90298E-01	3.12770E+00
9	6.03382E-02	1.14050E+00	7.51861E-01
10	6.03382E-02	1.29070E+00	-1.62309E+00
11	6.03382E-02	1.44090E+00	-3.99982E+00
12	6.03382E-02	1.59110E+00	-6.37566E+00
13	6.03382E-02	1.74130E+00	-8.75150E+00
14	1.49435E-01	1.82340E+00	-1.00501E+01
15	3.22271E-01	1.84120E+00	-1.03317E+01
16	1.63320E-01	1.78820E+00	-9.49347E+00
17	1.63320E-01	1.69826E+00	-8.07073E+00
18	1.63320E-01	1.63023E+00	-6.99466E+00
19	1.63320E-01	1.58460E+00	-6.27285E+00
20	1.63320E-01	1.56170E+00	-5.91066E+00

TRAJECTORY TIME STEP   5

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.24568E+01
2	6.03382E-02	8.90998E-02	1.15908E+01
3	6.03382E-02	2.39300E-01	1.00066E+01
4	6.03382E-02	3.89499E-01	8.42241E+00
5	6.03382E-02	5.39699E-01	6.83819E+00
6	6.03382E-02	6.89899E-01	5.25398E+00
7	6.03382E-02	8.40098E-01	3.66977E+00
8	6.03382E-02	9.90298E-01	2.08555E+00
9	6.03382E-02	1.14050E+00	5.01341E-01
10	6.03382E-02	1.29070E+00	-1.08287E+00
11	6.03382E-02	1.44090E+00	-2.66708E+00
12	6.03382E-02	1.59110E+00	-4.25130E+00
13	6.03382E-02	1.74130E+00	-5.83551E+00
14	1.49435E-01	1.82340E+00	-6.70145E+00
15	3.22271E-01	1.84120E+00	-6.88919E+00
16	1.63320E-01	1.78820E+00	-6.33025E+00
17	1.63320E-01	1.69826E+00	-5.38157E+00
18	1.63320E-01	1.63023E+00	-4.66401E+00
19	1.63320E-01	1.58460E+00	-4.18274E+00
20	1.63320E-01	1.56170E+00	-3.94124E+00

CASE   1 ANALYSIS
ELASTIC STRESSES AT X= 22.850

TRAJECTORY TIME STEP   1

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	5.89006E+00
2	6.03382E-02	8.90998E-02	5.48061E+00
3	6.03382E-02	2.39300E-01	4.73153E+00
4	6.03382E-02	3.89499E-01	3.98245E+00
5	6.03382E-02	5.39699E-01	3.23337E+00
6	6.03382E-02	6.89899E-01	2.48429E+00
7	6.03382E-02	8.40098E-01	1.73521E+00
8	6.03382E-02	9.90298E-01	9.86134E-01
9	6.03382E-02	1.14050E+00	2.37054E-01
10	6.03382E-02	1.29070E+00	-5.12025E-01
11	6.03382E-02	1.44090E+00	-1.26111E+00
12	6.03382E-02	1.59110E+00	-2.01018E+00
13	6.03382E-02	1.74130E+00	-2.75926E+00
14	1.49435E-01	1.82340E+00	-3.16071E+00
15	3.22271E-01	1.84120E+00	-3.25749E+00
16	1.63320E-01	1.78820E+00	-2.99320E+00
17	1.63320E-01	1.69826E+00	-2.54462E+00
18	1.63320E-01	1.63023E+00	-2.20533E+00
19	1.63320E-01	1.58460E+00	-1.97777E+00
20	1.63320E-01	1.56170E+00	-1.86358E+00

EXAMPLE PROBLEM 2 OUTPUT

TRAJECTORY TIME STEP 2

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	5.89006E+00
2	6.03382E-02	8.90998E-02	5.48061E+00
3	6.03382E-02	2.39300E-01	4.73153E+00
4	6.03382E-02	3.89499E-01	3.98245E+00
5	6.03382E-02	5.39699E-01	3.23337E+00
6	6.03382E-02	6.89899E-01	2.48429E+00
7	6.03382E-02	8.40098E-01	1.73521E+00
8	6.03382E-02	9.90298E-01	9.86134E-01
9	6.03382E-02	1.14050E+00	2.37054E-01
10	6.03382E-02	1.29070E+00	-5.12025E-01
11	6.03382E-02	1.44090E+00	-1.26111E+00
12	6.03382E-02	1.59110E+00	-2.01018E+00
13	6.03382E-02	1.74130E+00	-2.75926E+00
14	1.49435E-01	1.82340E+00	-3.16871E+00
15	3.22271E-01	1.84120E+00	-3.25749E+00
16	1.63320E-01	1.78820E+00	-2.99320E+00
17	1.63320E-01	1.69826E+00	-2.54462E+00
18	1.63320E-01	1.63023E+00	-2.20533E+00
19	1.63320E-01	1.58460E+00	-1.97777E+00
20	1.63320E-01	1.56170E+00	-1.86358E+00

TRAJECTORY TIME STEP 3

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.28602E+01
2	6.03382E-02	8.90998E-02	1.19662E+01
3	6.03382E-02	2.39300E-01	1.03107E+01
4	6.03382E-02	3.89499E-01	8.69520E+00
5	6.03382E-02	5.39699E-01	7.05967E+00
6	6.03382E-02	6.89899E-01	5.42415E+00
7	6.03382E-02	8.40098E-01	3.78863E+00
8	6.03382E-02	9.90298E-01	2.15310E+00
9	6.03382E-02	1.14050E+00	5.17579E-01
10	6.03382E-02	1.29070E+00	-1.11794E+00
11	6.03382E-02	1.44090E+00	-2.75347E+00
12	6.03382E-02	1.59110E+00	-4.38899E+00
13	6.03382E-02	1.74130E+00	-6.02452E+00
14	1.49435E-01	1.82340E+00	-6.91850E+00
15	3.22271E-01	1.84120E+00	-7.11232E+00
16	1.63320E-01	1.78820E+00	-6.53528E+00
17	1.63320E-01	1.69826E+00	-5.55587E+00
18	1.63320E-01	1.63023E+00	-4.81507E+00
19	1.63320E-01	1.58460E+00	-4.31821E+00
20	1.63320E-01	1.56170E+00	-4.06889E+00

TRAJECTORY TIME STEP 4

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.92865E+01
2	6.03382E-02	8.90998E-02	1.79458E+01
3	6.03382E-02	2.39300E-01	1.54930E+01
4	6.03382E-02	3.89499E-01	1.30402E+01
5	6.03382E-02	5.39699E-01	1.05874E+01
6	6.03382E-02	6.89899E-01	8.13459E+00
7	6.03382E-02	8.40098E-01	5.68180E+00
8	6.03382E-02	9.90298E-01	3.22900E+00
9	6.03382E-02	1.14050E+00	7.76212E-01
10	6.03382E-02	1.29070E+00	-1.67658E+00
11	6.03382E-02	1.44090E+00	-4.12937E+00
12	6.03382E-02	1.59110E+00	-6.58216E+00
13	6.03382E-02	1.74130E+00	-9.03495E+00
14	1.49435E-01	1.82340E+00	-1.03757E+01
15	3.22271E-01	1.84120E+00	-1.06663E+01
16	1.63320E-01	1.78820E+00	-9.80095E+00
17	1.63320E-01	1.69826E+00	-8.33213E+00
18	1.63320E-01	1.63023E+00	-7.22115E+00
19	1.63320E-01	1.58460E+00	-6.47602E+00
20	1.63320E-01	1.56170E+00	-6.10210E+00

TRAJECTORY TIME STEP 5

J	AREA(SQ.CM)	Y(CM)	STRESS(MPA)
1	4.12574E-01	6.99999E-03	1.28602E+01
2	6.03382E-02	8.90998E-02	1.19662E+01
3	6.03382E-02	2.39300E-01	1.03307E+01
4	6.03382E-02	3.89499E-01	8.69520E+00
5	6.03382E-02	5.39699E-01	7.05967E+00
6	6.03382E-02	6.89899E-01	5.42415E+00
7	6.03382E-02	8.40098E-01	3.78863E+00
8	6.03382E-02	9.90298E-01	2.15310E+00
9	6.03382E-02	1.14050E+00	5.17579E-01
10	6.03382E-02	1.29070E+00	-1.11794E+00
11	6.03382E-02	1.44090E+00	-2.75347E+00
12	6.03382E-02	1.59110E+00	-4.38899E+00
13	6.03382E-02	1.74130E+00	-6.02452E+00
14	1.49435E-01	1.82340E+00	-6.91850E+00
15	3.22271E-01	1.84120E+00	-7.11232E+00
16	1.63320E-01	1.78820E+00	-6.53528E+00
17	1.63320E-01	1.69826E+00	-5.55587E+00
18	1.63320E-01	1.63023E+00	-4.81507E+00
19	1.63320E-01	1.58460E+00	-4.31821E+00
20	1.63320E-01	1.56170E+00	-4.06889E+00

EXAMPLE PROBLEM 2 OUTPUT
CREEP PREDICTION COMPUTER PROGRAM

TPSC EXAMPLE PROBLEM 2   TIME HARD

SINGLE FACED CORRUGATION TPS

```
            SKIN GAGE = .0216 CM
            CORRUGATION GAGE = .0140 CM
            NUMBER OF CORRUGATIONS =  14
            PITCH LENGTH =   3.630 CM
            FLAT LENGTH =    .711 CM
            PANEL EDGE LENGTH =   .360 CM
            CORRUGATION ANGLE = 12.630 DEGREES
            PANEL DEPTH = 1.852 CM
            CALCULATED MOMENT OF INERTIA =  1.2036087 CM**4
            ELASTIC NEUTRAL AXIS = 1.188 CM

PANEL LENGTH = 45.70 CM
PANEL WIDTH =  51.60 CM


NEGATIVE BEAD
            RADIUS = -3.180 CM
            WIDTH = , 2.620 CM
APPLIED LOADS
            UNIFORM PRESSURE (PLATE OPTION)
```

BENDING MOMENT DISTRIBUTION

BEAM STATION (CM)

TIME	2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
					(CM KILOS)			
1.33	7.44	20.88	32.41	42.01	49.69	55.45	59.29	61.21
4.67	7.44	20.88	32.41	42.01	49.69	55.45	59.29	61.21
7.50	16.25	45.60	70.75	91.72	108.49	121.07	129.45	133.65
8.50	24.37	68.38	106.11	137.55	162.70	181.57	194.14	200.43
11.33	16.25	45.60	70.75	91.72	108.49	121.07	129.45	133.65

TRAJECTORY DATA

```
            TIME (MINUTES)    .
            PRESSURE (PA)
            TEMPERATURE (DEG K)
```

TIME		PRESSURE	MIDSPAN SKIN
START	END		TEMPERATURE
0.00	1.33	758.000	1122.0
1.33	4.67	758.000	1231.0
4.67	7.50	1655.000	1231.0
7.50	8.50	2482.000	1225.0
8.50	11.33	1655.000	1014.0

CYCLIC CREEP EQUATION DEFINITION

$$LN(STRAIN) = -2.89414E+00$$
$$-1.74300E-02 \ *(TIME)$$
$$-9.66548E+00 \ *(1,/TEMP)$$
$$5.48920E-01 \ *LN(TIME)$$
$$1.31015E+00 \ *LN(STRESS)$$
$$1.91310E-01 \ *LN(TEMP)$$
$$2.10000E-04 \ *TIME*STRESS*TEMP$$

```
    WHERE    TIME = HOURS
             TEMPERATURE = DEG K/1000.
             STRESS = MPA
```

B-85

EXAMPLE PROBLEM 2 OUTPUT
ELASTIC DEFLECTION SUMMARY

TIME(HR)	BEAM STATION (CM) 2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
1.33	.0016	.0031	.0044	.0056	.0066	.0073	.0077	.0079
4.67	.0016	.0031	.0044	.0056	.0066	.0073	.0077	.0079
7.50	.0034	.0067	.0097	.0123	.0144	.0159	.0169	.0172
8.50	.0051	.0100	.0145	.0184	.0216	.0239	.0253	.0258
11.33	.0034	.0067	.0097	.0123	.0144	.0159	.0169	.0172

FIRST CYCLE CREEP DEFLECTION SUMMARY

TIME	BEAM STATION (CM) 2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
1.33	.00006	.00011	.00017	.00021	.00025	.00028	.00030	.00030
4.67	.00016	.00031	.00045	.00058	.00068	.00076	.00081	.00082
7.50	.00032	.00063	.00092	.00118	.00139	.00155	.00164	.00168
8.50	.00041	.00080	.00117	.00149	.00176	.00196	.00208	.00212
11.33	.00045	.00088	.00128	.00163	.00192	.00214	.00227	.00232

CREEP DEFLECTION SUMMARY

CYCLE	BEAM STATION (CM) 2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
1	.00045	.00088	.00128	.00163	.00192	.00214	.00227	.00232
2	.00069	.00136	.00198	.00252	.00298	.00331	.00352	.00359
3	.00088	.00174	.00253	.00323	.00381	.00424	.00450	.00459
4	.00105	.00206	.00300	.00383	.00452	.00503	.00534	.00545

CREEP PREDICTION COMPUTER PROGRAM
CREEP STRAINS (PERCENT)
CYCLE 1

HEIGHT	BEAM STATION (CM) 2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	.0000798	.0003084	.0005477	.0007694	.0009587	.0011069	.0012053	.0012569
.0891	.0000762	.0002944	.0005227	.0007394	.0009211	.0010633	.0011550	.0012074
.2393	.0000692	.0002700	.0004727	.0006641	.0008272	.0009547	.0010398	.0010842
.3895	.0000615	.0002370	.0004206	.0005906	.0007355	.0008488	.0009246	.0009640
.5397	.0000532	.0002050	.0003637	.0005105	.0006357	.0007335	.0007992	.0008332
.6899	.0000441	.0001598	.0003013	.0004228	.0005265	.0006073	.0006620	.0005901
.8401	.0000340	.0001198	.0002321	.0003256	.0004054	.0004676	.0005100	.0005317
.9903	.0000225	.0000867	.0001536	.0002151	.0002679	.0003089	.0003373	.0003516
1.1405	.0000096	.0000350	.0000624	.0000876	.0001094	.0001262	.0001386	.0001444
1.2907	-.0000070	-.0000266	-.0000467	-.0000656	-.0000812	-.0000938	-.0001010	-.0001053
1.4409	-.0000196	-.0000753	-.0001331	-.0001869	-.0002322	-.0002680	-.0002907	-.0003031
1.5911	-.0000306	-.0001175	-.0002080	-.0002921	-.0003635	-.0004192	-.0004552	-.0004746
1.7413	-.0000471	-.0001552	-.0002748	-.0003861	-.0004803	-.0005543	-.0006022	-.0006279
1.8234	-.0000449	-.0001733	-.0003068	-.0004265	-.0005356	-.0006182	-.0006766	-.0007055
1.8412	-.0000459	-.0001772	-.0003137	-.0004370	-.0005437	-.0006276	-.0006879	-.0007173
1.7882	-.0000429	-.0001654	-.0002943	-.0004136	-.0005145	-.0005938	-.0006452	-.0006727
1.6983	-.0000369	-.0001448	-.0002564	-.0003601	-.0004479	-.0005170	-.0005616	-.0005855
1.6302	-.0000332	-.0001277	-.0002261	-.0003175	-.0003949	-.0004557	-.0004949	-.0005160
1.5846	-.0000301	-.0001158	-.0002049	-.0002878	-.0003579	-.0004130	-.0004484	-.0004676
1.5617	-.0000285	-.0001097	-.0001940	-.0002725	-.0003388	-.0003910	-.0004245	-.0004426

CREEP PREDICTION COMPUTER PROGRAM
RESIDUAL STRESSES (MPA)
CYCLE 1

HEIGHT	BEAM STATION (CM) 2.15	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	4.73E-03	1.81E-02	3.15E-02	4.44E-02	5.51E-02	6.33E-02	7.06E-02	7.36E-02
.0891	1.69E-03	6.53E-03	1.12E-02	9.05E-03	1.12E-02	1.29E-02	1.56E-02	1.62E-02
.2393	-3.31E-03	-1.62E-02	-1.99E-02	-2.77E-02	-3.43E-02	-3.94E-02	-4.17E-02	-4.34E-02
.3895	-7.19E-03	-2.70E-02	-4.79E-02	-6.68E-02	-8.29E-02	-9.53E-02	-1.03E-01	-1.09E-01
.5397	-1.04E-02	-3.92E-02	-6.95E-02	-9.69E-02	-1.20E-01	-1.38E-01	-1.50E-01	-1.57E-01
.6899	-1.24E-02	-4.71E-02	-8.35E-02	-1.16E-01	-1.45E-01	-1.66E-01	-1.81E-01	-1.89E-01
.8401	-1.31E-02	-4.97E-02	-8.81E-02	-1.23E-01	-1.53E-01	-1.76E-01	-1.92E-01	-2.00E-01
.9903	-1.19E-02	-4.53E-02	-7.98E-02	-1.11E-01	-1.38E-01	-1.59E-01	-1.74E-01	-1.81E-01
1.1405	-7.81E-03	-3.02E-02	-5.40E-02	-7.58E-02	-9.48E-02	-1.09E-01	-1.20E-01	-1.25E-01
1.2907	-3.75E-04	-1.75E-02	-3.66E-03	-5.37E-03	-6.85E-02	-7.90E-03	-1.00E-02	-1.05E-02
1.4409	2.44E-03	9.07E-03	1.55E-02	2.17E-02	2.63E-02	3.03E-02	3.13E-02	3.26E-02
1.5911	3.03E-03	9.09E-03	1.84E-02	2.52E-02	3.19E-02	3.67E-02	3.79E-02	3.95E-02
1.7413	1.63E-03	6.35E-03	1.09E-02	1.53E-02	1.82E-02	2.10E-02	2.63E-02	2.72E-02
1.8234	2.72E-04	6.22E-04	3.86E-04	-5.77E-03	-1.10E-03	-1.26E-03	2.63E-03	2.76E-03
1.8412	-6.61E-04	-6.72E-04	-1.90E-03	-7.95E-03	-1.07E-02	-1.23E-02	-7.90E-03	-8.22E-03
1.7882	8.95E-04	3.01E-03	6.63E-03	9.30E-03	1.08E-02	1.24E-02	1.09E-02	1.13E-02
1.6983	1.39E-03	8.35E-03	1.41E-02	1.98E-02	2.38E-02	3.45E-02	2.66E-02	2.66E-02
1.6302	2.84E-03	1.03E-02	1.77E-02	2.47E-02	3.00E-02	3.45E-02	3.53E-02	3.68E-02
1.5846	3.01E-03	1.10E-02	1.89E-02	2.64E-02	3.21E-02	3.69E-02	3.81E-02	3.97E-02
1.5617	3.04E-03	1.11E-02	1.91E-02	2.67E-02	3.25E-02	3.74E-02	3.87E-02	4.03E-02

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY • EAST

EXAMPLE PROBLEM 2 OUTPUT

CREEP STRAINS (PERCENT)

CYCLE 2

BEAM STATION (CM)

HEIGHT	2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	.0001236	.0004779	.0008498	.0011884	.0014811	.0017099	.0018797	.0019600
.0891	.0001181	.0004553	.0008094	.0011396	.0014199	.0016387	.0017900	.0018664
.2393	.0001063	.0004129	.0007236	.0010255	.0012776	.0014754	.0016095	.0016781
.3895	.0000945	.0003638	.0006458	.0009098	.0011331	.0013082	.0014270	.0014877
.5397	.0000818	.0003142	.0005573	.0007847	.0009769	.0011276	.0012299	.0012821
.6899	.0000677	.0002599	.0004608	.0006483	.0008069	.0009311	.0010155	.0010596
.8401								
1.7820								
1.6983	-.0000572	-.0002228	-.0003954	-.0005569	-.0006969	-.0008013	-.0008733	-.0009416
1.6302	-.0000512	-.0001964	-.0003486	-.0004908	-.0006111	-.0007057	-.0007694	-.0008022
1.5846	-.0000464	-.0001781	-.0003159	-.0004448	-.0005537	-.0006394	-.0006971	-.0007268
1.5617	-.0000440	-.0001686	-.0002991	-.0004211	-.0005242	-.0006053	-.0006599	-.0006880

CREEP PREDICTION COMPUTER PROGRAM

RESIDUAL STRESSES (MPA)

CYCLE 2

BEAM STATION (CM)

HEIGHT	2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	6.50E-03	2.44E-02	4.21E-02	7.01E-02	8.69E-02	1.01E-01	9.09E-02	9.46E-02
.0891	1.78E-03	7.97E-03	1.34E-02	1.86E-02	2.34E-02	2.82E-02	2.81E-02	2.93E-02
.2393	-4.44E-03	-2.05E-02	-2.27E-02	-4.14E-02	-5.12E-02	-5.93E-02	-6.43E-02	-6.68E-02
.3895	-1.07E-02	-3.97E-02	-6.98E-02	-9.42E-02	-1.23E-01	-1.41E-01	-1.54E-01	-1.60E-01
.5397	-1.56E-02	-5.81E-02	-1.02E-01	-1.45E-01	-1.78E-01	-2.05E-01	-2.23E-01	-2.32E-01
.5899	-1.87E-02	-7.02E-02	-1.23E-01	-1.73E-01	-2.14E-01	-2.47E-01	-2.69E-01	-2.80E-01
.8403	-1.98E-02	-7.43E-02	-1.31E-01	-1.83E-01	-2.27E-01	-2.61E-01	-2.85E-01	-2.97E-01
1.1405	-1.79E-02	-6.77E-02	-1.19E-01	-1.65E-01	-2.05E-01	-2.36E-01	-2.58E-01	-2.69E-01
1.2907	-1.19E-02	-4.60E-02	-8.16E-02	-1.15E-01	-1.43E-01	-1.65E-01	-1.79E-01	-1.87E-01
1.4409	-5.43E-04	-2.89E-03	-5.14E-03	-7.92E-03	-9.81E-03	-1.12E-02	-1.33E-02	-1.39E-02
1.5911	3.82E-03	1.33E-02	2.32E-02	3.26E-02	4.01E-02	4.63E-02	4.96E-02	5.16E-02
1.7413	4.58E-03	1.60E-02	2.79E-02	3.94E-02	4.84E-02	5.61E-02	6.01E-02	6.26E-02
1.8234	2.34E-03	9.20E-03	1.61E-02	2.32E-02	2.83E-02	3.30E-02	3.49E-02	3.63E-02
1.8412	3.87E-04	-2.10E-04	-5.91E-04	-5.74E-03	-3.93E-03	-2.92E-03	3.70E-03	3.85E-03
1.7882	-1.06E-03	-2.59E-03	-4.76E-03	-6.75E-03	-8.59E-03	-1.01E-02	-1.20E-02	-1.25E-02
1.6983	1.17E-03	2.87E-03	7.00E-03	1.06E-02	1.28E-02	1.60E-02	1.42E-02	1.48E-02
1.6302	2.44E-03	1.20E-02	2.09E-02	2.98E-02	3.65E-02	4.25E-02	5.65E-02	4.71E-02
1.5846	4.34E-03	1.50E-02	2.62E-02	3.71E-02	4.56E-02	5.28E-02	5.65E-02	5.89E-02
1.5617	4.60E-03	1.61E-02	2.81E-02	3.96E-02	4.87E-02	5.64E-02	6.05E-02	6.30E-02
	4.65E-03	1.63E-02	2.85E-02	4.01E-02	4.93E-02	5.71E-02	6.12E-02	6.37E-02

CREEP PREDICTION COMPUTER PROGRAM

CREEP STRAINS (PERCENT)

CYCLE 3

BEAM STATION (CM)

HEIGHT	2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	.0001579	.0006129	.0010446	.0015237	.0018998	.0022030	.0024020	.0025047
.0891	.0001509	.0005818	.0010314	.0014623	.0018192	.0021006	.0022790	.0023763
.2393	.0001368	.0005272	.0009243	.0013144	.0016387	.0018940	.0020545	.0021420
.3895	.0001207	.0004649	.0008213	.0011637	.0014509	.0016763	.0018183	.0018956
.5397	.0001042	.0004009	.0007079	.0010016	.0012488	.0014424	.0015645	.0016309
.5899	.0000862	.0003312	.0005846	.0008260	.0010299	.0011892	.0012898	.0013444
.8401	.0000663				.0007900	.0009118	.0009888	.0010306
1.7882	-.0000843	-.0003241	-.0005750	-.0008116	-.0010137	-.0011634	-.0012703	-.0014231
1.6983	-.0000727	-.0002845	-.0005033	-.0007112	-.0008861	-.0010240	-.0011132	-.0013245
1.6302	-.0000654	-.0002507	-.0004435	-.0006262	-.0007802	-.0009014	-.0009803	-.0011607
1.5846	-.0000593	-.0002272	-.0004019	-.0005671	-.0007065	-.0008162	-.0008878	-.0010220
1.5617	-.0000562	-.0002151	-.0003805	-.0005367	-.0006686	-.0007725	-.0008403	-.0008761

B-87

EXAMPLE PROBLEM 2 OUTPUT

CREEP PREDICTION COMPUTER PROGRAM
RESIDUAL STRESSES (MPA)
CYCLE   3

BEAM STATION (CM)

HEIGHT	2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	8.52E-03	2.88E-02	5.37E-02	8.70E-02	1.08E-01	1.13E-01	1.18E-01	1.22E-01
.0891	2.45E-03	1.09E-02	1.94E-02	1.95E-02	2.92E-02	3.54E-02	4.89E-02	5.09E-02
.2393	-6.86E-03	-2.49E-02	-3.00E-02	-5.47E-02	-6.87E-02	-8.04E-02	-7.76E-02	-8.07E-02
.3895	-1.34E-02	-5.01E-02	-8.49E-02	-1.25E-01	-1.56E-01	-1.81E-01	-1.88E-01	-1.96E-01
.5397	-1.95E-02	-7.39E-02	-1.26E-01	-1.90E-01	-2.25E-01	-2.59E-01	-2.74E-01	-2.85E-01
.6899	-2.35E-02	-8.80E-02	-1.52E-01	-2.16E-01	-2.69E-01	-3.10E-01	-3.31E-01	-3.45E-01
.8401	-2.43E-02	-9.13E-02	-1.62E-01	-2.29E-01	-2.85E-01	-3.28E-01	-3.52E-01	-3.67E-01
.9903	-2.25E-02	-8.52E-02	-1.48E-01	-2.10E-01	-2.59E-01	-2.98E-01	-3.21E-01	-3.34E-01
1.1415	-1.50E-02	-5.81E-02	-1.02E-01	-1.46E-01	-1.82E-01	-2.10E-01	-2.25E-01	-2.35E-01
1.2907	-6.31E-04	-3.98E-03	-6.92E-03	-1.15E-02	-1.49E-02	-1.71E-02	-1.75E-02	-1.82E-02
1.4409	4.89E-03	1.65E-02	2.86E-02	3.91E-02	4.81E-02	5.56E-02	6.09E-02	6.34E-02
1.5911	5.84E-03	1.99E-02	3.41E-02	4.78E-02	5.91E-02	6.85E-02	7.37E-02	7.67E-02
1.7413	2.33E-03	1.15E-02	1.90E-02	2.82E-02	3.47E-02	4.07E-02	4.22E-02	4.40E-02
1.8234	5.56E-04	-8.61E-04	-3.09E-03	-6.25E-03	-4.76E-03	-2.23E-03	5.49E-04	5.54E-04
1.8412	-1.02E-03	-2.16E-03	-9.03E-03	-8.55E-03	-1.40E-02	-1.27E-02	-1.30E-02	-1.36E-02
1.7882	-1.21E-03	2.99E-02	6.04E-03	8.19E-03	1.30E-02	1.24E-02	1.04E-02	1.09E-02
1.6983	2.54E-03	1.49E-02	2.51E-02	3.62E-02	4.47E-02	5.21E-02	5.50E-02	5.73E-02
1.6302	5.54E-03	1.87E-02	3.19E-02	4.51E-02	5.57E-02	6.46E-02	6.92E-02	7.20E-02
1.5846	5.87E-03	2.00E-02	3.44E-02	4.81E-02	5.94E-02	6.88E-02	7.41E-02	7.72E-02
1.5617	5.94E-03	2.03E-02	3.49E-02	4.86E-02	6.01E-02	6.96E-02	7.51E-02	7.82E-02

CREEP PREDICTION COMPUTER PROGRAM
CREEP STRAINS (PERCENT)
CYCLE   4

BEAM STATION (CM)

HEIGHT	2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	.0001882	.0007246	.0012879	.0018099	.0022565	.0026068	.0028425	.0029641
.0891	.0001794	.0006913	.0012219	.0017397	.0021575	.0024920	.0027075	.0028231
.2393	.0001636	.0006237	.0011918	.0015630	.0019448	.0022477	.0024400	.0025439
.3895	.0001434	.0005500	.0009725	.0013823	.0017193	.0019863	.0021560	.0022477
.5397	.0001237	.0004738	.0008370	.0011881	.0014777	.0017066	.0018522	.0019308
.6899	.0001023	.0003910	.0006901	.0009786	.0012170	.0014049	.0015246	.0015891
.8401	.0000786	.0003011	.0005291	.0007497	.0009323	.0010756	.0011669	.0012162
.9903	.0000516	.0001977	.0003475	.0004939	.0006123	.0007045	.0007641	.0007962
1.1415	.0000207	.0000801	.0001405	.0002013	.0002495	.0002886	.0003115	.0003246
1.2907	-.0000163	-.0000515	-.0001103	-.0001529	-.0001898	-.0002198	-.0002404	-.0002507
1.4409	-.0000458	-.0001743	-.0003099	-.0004358	-.0005417	-.0006261	-.0006821	-.0007111
1.5911	-.0000714	-.0002726	-.0004941	-.0006831	-.0008496	-.0009818	-.0010685	-.0011140
1.7413	-.0000933	-.0003611	-.0006410	-.0009065	-.0011277	-.0013035	-.0014180	-.0014785
1.8234	-.0001059	-.0004033	-.0007147	-.0010085	-.0012586	-.0014565	-.0015856	-.0016533
1.8412	-.0001168	-.0004122	-.0007305	-.0010346	-.0012893	-.0014890	-.0016216	-.0016908
1.7882	-.0001000	-.0003450	-.0006871	-.0010602	-.0012019	-.0013837	-.0015041	-.0015683
1.6983	-.0000860	-.0003366	-.0005975	-.0008445	-.0010506	-.0012142	-.0013210	-.0013773
1.6302	-.0000776	-.0002965	-.0005264	-.0007433	-.0009245	-.0010684	-.0011626	-.0012122
1.5846	-.0000704	-.0002686	-.0004769	-.0006729	-.0008369	-.0009672	-.0010526	-.0010975
1.5617	-.0000666	-.0002542	-.0004515	-.0006368	-.0007920	-.0009152	-.0009962	-.0010386

CREEP PREDICTION COMPUTER PROGRAM
RESIDUAL STRESSES (MPA)
CYCLE   4

BEAM STATION (CM)

HEIGHT	2.86	5.71	8.57	11.42	14.28	17.14	19.99	22.85
.0070	9.10E-03	3.68E-02	6.24E-02	1.03E-01	1.25E-01	1.45E-01	1.52E-01	1.58E-01
.0891	2.55E-03	1.07E-02	2.56E-02	1.96E-02	3.67E-02	4.34E-02	5.55E-02	5.78E-02
.2393	-9.85E-03	-2.78E-02	-2.08E-02	-6.72E-02	-8.16E-02	-9.51E-02	-9.33E-02	-9.70E-02
.3895	-1.65E-02	-5.79E-02	-9.80E-02	-1.48E-01	-1.82E-01	-2.10E-01	-2.18E-01	-2.28E-01
.5397	-2.31E-02	-8.45E-02	-1.45E-01	-2.11E-01	-2.61E-01	-3.00E-01	-3.18E-01	-3.31E-01
.6899	-2.77E-02	-1.02E-01	-1.76E-01	-2.53E-01	-3.13E-01	-3.59E-01	-3.84E-01	-4.00E-01
.8401	-2.93E-02	-1.08E-01	-1.88E-01	-2.68E-01	-3.32E-01	-3.81E-01	-4.09E-01	-4.25E-01
.9903	-2.66E-02	-9.89E-02	-1.71E-01	-2.45E-01	-3.02E-01	-3.44E-01	-3.71E-01	-3.86E-01
1.1415	-1.78E-02	-6.85E-02	-1.19E-01	-1.72E-01	-2.13E-01	-2.46E-01	-2.64E-01	-2.75E-01
1.2907	-8.78E-04	-4.94E-03	-7.38E-03	-1.40E-02	-1.88E-02	-2.07E-02	-2.11E-02	-2.19E-02
1.4409	5.65E-03	1.89E-02	3.41E-02	4.56E-02	5.49E-02	6.41E-02	7.03E-02	7.30E-02
1.5911	6.81E-03	2.28E-02	4.06E-02	5.61E-02	6.79E-02	7.92E-02	8.56E-02	8.90E-02
1.7413	2.81E-03	1.31E-02	2.32E-02	3.38E-02	3.99E-02	4.74E-02	4.97E-02	5.18E-02
1.8234	1.55E-03	-2.20E-03	-2.93E-03	-6.11E-03	-4.75E-03	-1.48E-03	4.97E-03	5.17E-03
1.8412	-1.32E-03	-4.07E-03	-8.77E-03	-9.22E-03	-1.10E-02	-1.31E-02	-2.07E-02	-2.16E-02
1.7882	-1.38E-03	-4.89E-03	1.38E-02	4.70E-03	1.37E-02	-1.31E-02	-1.39E-02	-1.45E-02
1.6983	2.51E-03	1.70E-02	3.02E-02	4.30E-02	5.14E-02	6.09E-02	6.77E-02	7.07E-02
1.6302	6.47E-03	2.14E-02	3.80E-02	5.31E-02	6.40E-02	7.48E-02	8.04E-02	8.37E-02
1.5846	6.85E-03	2.29E-02	4.08E-02	5.64E-02	6.83E-02	7.96E-02	8.60E-02	8.95E-02
1.5617	6.91E-03	2.32E-02	4.14E-02	5.70E-02	6.90E-02	8.04E-02	8.71E-02	9.06E-02

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

APPENDIX C

TPSC

PROGRAM LISTING

MCDONNELL DOUGLAS ASTRONAUTICS COMPANY - EAST

```
      PROGRAM TPSC(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)         IPSC   10
      DIMENSION  PRESS (10)   ,  TEMP (10)   ,  DXTIME (10) , XTP (20)  , IPSC   20
     1          XTEMP (24)  ,  YTP (60)   ,  YTEMP (24)  , FORC(60)   , IPSC   30
     2          ASTRAT (50) ,  ETEMP (24) ,  C (4)       , D (4)      , IPSC   40
     3          STRESS (60) ,  A (60)     ,  Y (60)      , BETA (10)  , IPSC   50
     4          XMOM (10)   ,  ECOEFF (4) ,  THETAT (10) , XPRINT (10), IPSC   60
     5          X (20)      ,  IPRINT (10), KCYCLE (10) , YNA (10)   , IPSC   70
     6          Z (75)      ,              , PLOAD(10)   , RESSTR(60),CSTRAN(60)  IPSC   80
     7, STRES(21)                                                     IPSC   90
      DIMENSION  E(10,60)    ,  T(20,60) ,                            IPSC  100
     1          THETAE (20,10) , STRANE (10,60) , STRESE (10,60) ,    IPSC  110
     2          DEFL (10,10)  , DEFLE (10,10) , THETAP (20,10) ,      IPSC  120
     3          DEFLIN (10,10), THET(20,10),RESSIN(10,60)             IPSC  130
     4  , PLAMOM(10,10) ,  PRTMOM(10,10)                              IPSC  140
      DIMENSION  RESP(10,60,10),PSTRAN(10,60,10)                      IPSC  150
      COMMON PLAMOM,PRTMOM,INDPLA                                     IPSC  160
      NAMELIST /CREEP/ DEPTH   , PHICOR  , PITCH   , FLAT    , EDGE  , IPSC  170
     1NCOR    , TS      , TC      , XLGTH   , TR      , NRIB  , RIBFLG, IPSC  180
     2ZPNED1  , ZPNED2  , NZEE    , TZEE    , ZEESF   , ZEESF1, ZEEFF, IPSC  190
     3ZEEFF1  , BWID    , BDEJ    , BRAD    ,                         IPSC  200
     4PRESS   , TEMP    , DXTIME  , PLOAD   ,                         IPSC  210
     5ALEN    , XNU     , PANWID  , C       , D       , E     , NTIME, IPSC  220
     6XTEMP   , NEWCAS  , YTEMP   , EMOD    , ETEMP   , INDGEO, IPSC  230
     7INORD   , INDLOD  , INDSUP  , INDPLA  , INDTFL  , INDTFD, KCYCLE, IPSC  240
     8INDMOD  , INDELA  ,                                             IPSC  250
     9NCYCLE  , NUMCYC  , ITCON   , NTCON   , ECOEFF  , Z     , IPSC  260
     AHARDOP  , TMAX    , INCYC   , ITIME   , IEQNTP  , LINTP , IDIMEN, IPSC  270
     BILOAD   , IEQNST  , NSTAT   , SEC     , NSECT   , NBSECT, IPSC  280
     CIRESID  , RESSIN  , ESTIFF  ,INDD2    , INDSTR  ,DETWO           IPSC  290
C                                                                     IPSC  300
      LOOP = 0                                                        IPSC  310
      NEWCAS=1                                                        IPSC  320
   10 DO 20 II=1,75                                                   IPSC  330
   20 Z(II)=0.                                                        IPSC  340
C                                                                     IPSC  350
C                                                                     IPSC  360
C     DEFAULT VALUES                                                  IPSC  370
C                                                                     IPSC  380
      IRESID=0                                                        IPSC  390
      DO 30   J=1,60                                                  IPSC  400
      RESSTR(J)=0.                                                    IPSC  410
   30 CONTINUE                                                        IPSC  420
      DO 40 LL=1,10                                                   IPSC  430
      PLOAD(LL)=0.                                                    IPSC  440
      PRESS(LL)=0.                                                    IPSC  450
   40 TEMP(LL)=0.                                                     IPSC  460
      ITIME=0                                                         IPSC  470
      IEQNTP=0                                                        IPSC  480
      IINTP=0                                                         IPSC  490
      IDIMEN=0                                                        IPSC  500
      ILOAD=0                                                         IPSC  510
      IEQNST=0                                                        IPSC  520
      NTCON=1                                                         IPSC  530
      ITCON=1                                                         IPSC  540
      D(1)=1.                                                         IPSC  550
      INDTFD=0                                                        IPSC  560
```

```
      C(1)=1.
      INOTFL=0
      INDLOD=0
      INDSUP=0
      INCYC=1
      INDFLA=0
      HARDOP=1
      INDSTR=0
      INDLOD=0
      S=1.
      INDRO=0
      INDPLA=0
      DEPTH=0.
      PITCH=0.
      FLAT=0.
      EDGE=0.
      TS=0.
      TC=0.
      XLGTH=0.
      TR=0.
      RIBFLG=0.
      ZPNED1=0.
      ZPNED2=0.
      TZEE=0.
      ZEESE=0.
      ZEESE1=0.
      ZEEFF=0.
      ZEEFF1=0.
      BWID=0.
      BDEP=0.
      BRAD=0.
      ALEN=0.
      PANWID=0.
      INDD2=0
      INDPLA=0
      D(2)=0.
      D(3)=0.
      D(4)=0.
  C
  C
      DUMLGT = 0.0
      NSTAT=6
      NSECT=10
      SEC=10.
      NRSECT=6
      READ (5,1760) AM1,AM2,AM3,AM4,AM5
      READ ( 5,CREEP )
      WRITE(6,CREEP)
      NSECTT=NSECT+5
      NSECT1=NSECT+1
      IF(ILOAD.NE.0)GO TO 6)
      DO 50 LL=1,NTIME
      PLOAD(LL)=PLOAD(LL)/.45359
      PRESS(LL)=PRESS(LL)/6894.8
   50 CONTINUE
   60 CONTINUE
      IF(IDIMEN.NE.0)GO TO 70
      DEPTH=DEPTH   /2.540005
      PITCH=PITCH   /2.540005
```

```
IPSC  570
IPSC  580
IPSC  590
IPSC  600
IPSC  610
IPSC  620
IPSC  630
IPSC  640
IPSC  650
IPSC  660
IPSC  670
IPSC  680
IPSC  690
IPSC  700
IPSC  710
IPSC  720
IPSC  730
IPSC  740
IPSC  750
IPSC  760
IPSC  770
IPSC  780
IPSC  790
IPSC  800
IPSC  810
IPSC  820
IPSC  830
IPSC  840
IPSC  850
IPSC  860
IPSC  870
IPSC  880
IPSC  890
IPSC  900
IPSC  910
IPSC  920
IPSC  930
IPSC  940
IPSC  950
IPSC  960
IPSC  970
IPSC  980
IPSC  990
IPSC1000
IPSC1010
IPSC1020
IPSC1030
IPSC1040
IPSC1050
IPSC1060
IPSC1070
IPSC1080
IPSC1090
IPSC1100
IPSC1110
IPSC1120
IPSC1130
IPSC1140
IPSC1150
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```
      FLAT=FLAT       /2.540005                                                  IPSC1160
      EDGE=EDGE       /2.540005                                                  IPSC1170
      TS=TS           /2.540005                                                  IPSC1180
      TC=TC           /2.540005                                                  IPSC1190
      TR=TR           /2.540005                                                  IPSC1200
      XLGTH=XLGTH     /2.540005                                                  IPSC1210
      RIBFLG=RIBFLG   /2.540005                                                  IPSC1220
      ZPNED1=ZPNED1   /2.540005                                                  IPSC1230
      ZPNED2=ZPNED2   /2.540005                                                  IPSC1240
      TZEE=TZEE       /2.540005                                                  IPSC1250
      ZEESF1=ZEESF1   /2.540005                                                  IPSC1260
      ZEEFF=ZEEFF     /2.540005                                                  IPSC1270
      ZEEFF1=ZEEFF1   /2.540005                                                  IPSC1280
      BWID=BWID       /2.540005                                                  IPSC1290
      BDEP=BDEP       /2.540005                                                  IPSC1300
      BRAD=BRAD       /2.540005                                                  IPSC1310
      ALEN=ALEN       /2.540005                                                  IPSC1320
      PANWID=PANWID   /2.540005                                                  IPSC1330
      ZEESF=ZEESF     /2.540005                                                  IPSC1340
      ESTIFF=ESTIFF/(2.540005**4.)                                              IPSC1350
   70 CONTINUE                                                                   IPSC1360
      IF(XLGTH.EQ.DUMLGT) GO TO 100                                              IPSC1370
      DX=XLGTH/(2.*NSTAT)                                                        IPSC1380
      DO 80 I=1,NSTAT                                                            IPSC1390
   80 X(I) = I*DX                                                                IPSC1400
      DUMLGT = XLGTH                                                             IPSC1410
      DO 90 II=1,NSTAT                                                           IPSC1420
      IPRINT(II) = II                                                            IPSC1430
   90 XPRINT(II) = IPRINT(II)*DX                                                 IPSC1440
  100 CALL GEOM(          INDGEO , DEPTH  , TR     , NRIB   , PITCH  ,           IPSC1450
     1RIBFLG , TS     , TC     , NCUR   , EDGE   , PHICUR , FLAT   ;            IPSC1460
     2TZEE   , NZEE   , ZPNED1 , ZPNED2 , ZEEFF1 , ZEESF1 , ZEEFF  ;            IPSC1470
     3ZEESF  , A      , Y      , DY     , PANWID ,                              IPSC1480
     4 NSECT , SEC  , S )                                                       IPSC1490
      IF(S.LT.0.)GO TO 1740                                                      IPSC1500
C---- CALCULATION OF GEOMETRY OF BEAD; INDBD = 1                                 IPSC1510
      IF(INDBD.EQ.0) GO TO 220                                                   IPSC1520
      H1 = SQRT(BRAD**2 - (.5*BWID)**2)                                          IPSC1530
      ANGLE = BWID/(2.0*H1)                                                      IPSC1540
      ALPHA = ATAN(ANGLE)                                                        IPSC1550
      AREABD = ABS(.2*ALPHA*BRAD*TS)                                             IPSC1560
C---- RIB SUPPORT GEOMETRY; INDGEO = 1                                           IPSC1570
C---- CORRUGATION SUPPORT GEOMETRY; INDGEO = 2                                   IPSC1580
C---- ZEE SUPPORT GEOMETRY; INDGEO = 3                                           IPSC1590
      IF(INDGEO - 2) 110,130,150                                                 IPSC1600
  110 A(NSECT)=A(NSECT)-TS*BWID*(NRIB-1)                                         IPSC1610
      DO 120 I=NSECT1,NSECT                                                      IPSC1620
  120 A(I)=AREABD*(NRIB-1)*2.                                                    IPSC1630
      GO TO 170                                                                  IPSC1640
  130 A(NSECT)=A(NSECT)-TS*BWID*NCUR                                            IPSC1650
      DO 140 I=NSECT1,NSECT                                                      IPSC1660
  140 A(I)=AREABD*NCUR*2.                                                       IPSC1670
      GO TO 170                                                                  IPSC1680
  150 A(NSECT)=A(NSECT)-TS*BWID*(NZEE-1)                                         IPSC1690
      DO 160 I=NSECT1,NSECT                                                      IPSC1700
  160 A(I)=AREABD*(NZEE-1)*2.                                                    IPSC1710
  170 DO 180 J=NSECT1,NSECT                                                      IPSC1720
  180 BETA(J)=(1.10-(J-NSECT)*.20)*ALPHA                                         IPSC1730
      IF(BRAD.GT.0.0) GO TO 200                                                  IPSC1740
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      XX2=ABS(BRAD)
      XX1=Y(NSECT)+H1
      DO 190 K=NSECT1,NSECT                                              IPSC1750
  190 Y(K)=XX1-XX2*COS(BETA(K))                                         IPSC1760
      GO TO 220                                                          IPSC1770
  200 XX1=Y(NSECT)-H1                                                    IPSC1780
      DO 210 L=NSECT1,NSECT                                             IPSC1790
  210 Y(L)=XX1+BRAD*COS(BETA(L))                                        IPSC1800
C---- CALCULATION OF SECTION PROPERTIES OF BEAM                         IPSC1810
  220 NAREA=NSECT                                                       IPSC1820
      IF(INDBD.NE.0) NAREA=NSECT1                                       IPSC1830
      AYTOT = 0.0                                                        IPSC1840
      ATOT = 0.0                                                         IPSC1850
      AYYTOT = 0.0                                                       IPSC1860
      DO 230 J=1,NAREA                                                   IPSC1870
      AYTOT = AYTOT + A(J)*Y(J)                                          IPSC1880
      ATOT = ATOT + A(J)                                                 IPSC1890
  230 AYYTOT = AYYTOT + A(J)*(Y(J)**2)                                  IPSC1900
      YBAR = AYTOT/ATOT                                                  IPSC1910
      XI = AYYTOT - ATOT*(YBAR**2)                                      IPSC1920
      DO 1550 I=1,NSTAT                                                  IPSC1930
C                                                                        IPSC1940
CC --- BEAM STATION LOOP                                                IPSC1950
C                                                                        IPSC1960
      LOOPCA=LOOP+1                                                      IPSC1970
      IF(IDIMEN.EQ.0)GO TO 250                                          IPSC1980
      WRITE(6,1770)LOOPCA,X(I)                                          IPSC1990
      GO TO 260                                                          IPSC2000
  250 SUBSTX=X(I)*2.54                                                  IPSC2010
      WRITE(6,1770)LOOPCA,SUBSTX                                        IPSC2020
  260 CONTINUE                                                          IPSC2030
      IF(IRESID.NE.0)GO TO 280                                          IPSC2040
      DO 270 J=1,NAREA                                                   IPSC2050
  270 RESSTR(J)=RESSIN(I,J)                                             IPSC2060
  280 CONTINUE                                                          IPSC2070
      TIME1 = 0.0                                                        IPSC2080
      TIME=0.                                                            IPSC2090
C---- CALCULATION OF TEMPERATURE AS A FUNCTION OF BEAM LENGTH           IPSC2100
      IF(INDTEL.EQ.1) GO TO 300                                         IPSC2110
C---- TEMPERATURE CALCULATED VIA EQUATION; INDTEL = 0                   IPSC2120
C---- EQUATION METHOD IS ALSO USED IF TEMPERATURE IS CONSTANT           IPSC2130
      XTP(I) = C(1) + C(2)*X(I) + C(3)*X(I)**2 + C(4)*X(I)**3           IPSC2140
      GO TO 310                                                          IPSC2150
C---- TEMPERATURE CALCULATED VIA TABLE-LOOKUP; INDTEL = 1               IPSC2160
  300 XIN = X(I)                                                        IPSC2170
      CALL TBLKP(XTEMP,1,XIN,0.0,XTMP,IE)                               IPSC2180
      XTP(I) = XTMP                                                      IPSC2190
      IF(IE.NE.0) WRITE ( 6,1780 ) XIN                                  IPSC2200
  310 CONTINUE                                                          IPSC2210
C---- CALCULATION OF TEMPERATURE AS A FUNCTION OF BEAM DEPTH            IPSC2220
      IF(INDTED.EQ.1) GO TO 330                                         IPSC2230
C---- TEMPERATURE CALCULATED VIA EQUATION; INDTED = 0                   IPSC2240
C---- EQUATION METHOD IS ALSO USED IF TEMPERATURE IS CONSTANT           IPSC2250
      DO 320 J=1,NAREA                                                   IPSC2260
  320 YTP(J) = D(1) + D(2)*Y(J) + D(3)*Y(J)**2 + D(4)*Y(J)**3           IPSC2270
      GO TO 350                                                          IPSC2280
C---- TEMPERATURE CALCULATED VIA TABLE-LOOKUP; INDTED = 1               IPSC2290
  330 DO 340 J=1,NAREA                                                  IPSC2300
      XIN = Y(J)                                                         IPSC2310
                                                                         IPSC2320
                                                                         IPSC2330
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          CALL TBLKP(YTEMP,1,XIN,0.0,YTMP,IE)                              IPSC2340
          YTP(J) = YTMP                                                    IPSC2350
          IF(IE.NE.0) WRITE ( 6,1790 ) XIN                                 IPSC2360
      340 CONTINUE                                                         IPSC2370
      350 CONTINUE                                                         IPSC2380
C---- CALCULATION OF TOTAL  TEMPERATURES AT X AND AT ANY TIME IN THE CYCL IPSC2390
          DO 370 K=1,NTIME                                                 IPSC2400
          DO 360 L=1,NAREA                                                 IPSC2410
          T(K,L) = TEMP(K)*XTP(I)*YTP(L)                                   IPSC2420
      360 CONTINUE                                                         IPSC2430
      370 CONTINUE                                                         IPSC2440
C---- CALCULATION OF MODULUS OF ELASTICITY AS A FUNCTION OF TEMPERATURE    IPSC2450
          IF(INDMOD.EQ.1) GO TO 400                                       IPSC2460
C---- MODULUS OF ELASTICITY CALCULATED VIA EQUATION; INDMOD = 0            IPSC2470
C---- EQUATION METHOD IS ALSO USED IF MODULUS IS CONSTANT                  IPSC2480
          DO 390 K=1,NTIME                                                 IPSC2490
          DO 380 L=1,NAREA                                                 IPSC2500
      380 E(K,L) = ECOEFF(1) + ECOEFF(2)*T(K,L) + ECOEFF(3)*T(K,L)**2 +    IPSC2510
         1ECOEFF(4)*T(K,L)**3                                             IPSC2520
      390 CONTINUE                                                         IPSC2530
          GO TO 430                                                        IPSC2540
C---- MODULUS OF ELASTICITY CALCULATED VIA TABLE-LOOKUP; INDMOD = 1        IPSC2550
      400 DO 420 K=1,NTIME                                                 IPSC2560
          DO 410 L=1,NAREA                                                 IPSC2570
          TIN = T(K,L)                                                     IPSC2580
          CALL TBLKP(ETEMP,1,TIN,0.0,EMOD,IE)                              IPSC2590
          E(K,L) = EMOD                                                    IPSC2600
      410 IF(IE.NE.0) WRITE ( 6,1800 ) TIN                                 IPSC2610
      420 CONTINUE                                                         IPSC2620
C---- CALCULATION OF MOMENTS AT X AND TIME IN THE CYCLE; INDLUD = 1 (POI  IPSC2630
      430 CONTINUE                                                         IPSC2640
          IF(ILOAD.EQ.1)GO TO 450                                         IPSC2650
          DO 440 K=1,NTIME                                                 IPSC2660
          DO 440 L=1,NAREA                                                 IPSC2670
      440 E(K,L)=E(K,L)/6894.8                                            IPSC2580
      450 CONTINUE                                                         IPSC2590
C                                                                          IPSC2700
C     PLATE SOLUTION                                                       IPSC2710
C                                                                          IPSC2720
          IF(INDLUD.EQ.1) GO TO 630                                       IPSC2730
          IF(INDPLA.EQ.0)GO TO 560                                        IPSC2740
          DEONE=XI/PANWID                                                 IPSC2750
          IF(INDO2.EQ.1)GO TO 460                                         IPSC2760
          DETWO=             TS*TS*TS/(12.*(1.-XNU*XNU))                  IPSC2770
      460 CONTINUE                                                         IPSC2780
          IF(XLGTH.GT.PANWID)GO TO 560                                    IPSC2790
          IF(DETWO.GT.DEONE)GO TO 560                                     IPSC2800
C                                                                          IPSC2810
C     SOLUTION FOR LEKHNITSKII MAX MOMENT                                  IPSC2820
C                                                                          IPSC2830
          DRAT=DEONE/DETWO                                                IPSC2840
          IF(DRAT.GT.26.)GO TO 520                                        IPSC2850
          ELEK=(PANWID/XLGTH)*(DEONE/DETWO)**.25                          IPSC2860
          IF(ELEK.GE.1.AND.ELEK.LT.1.5)GO TO 470                          IPSC2870
          IF(ELEK.GE.1.5.AND.ELEK.LT.2.0)GO TO 480                        IPSC2880
          IF(ELEK.GE.2.0.AND.ELEK.LT.2.5)GO TO 490                        IPSC2890
          IF(ELEK.GE.2.5.AND.ELEK.LT.3.0)GO TO 500                        IPSC2900
          IF(ELEK.GE.3.0.AND.ELEK.LT.5.0)GO TO 510                        IPSC2910
          IF(ELEK.GE.5.0)GO TO 520                                        IPSC2920
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470  XMU11=.0358-(ELEK-1.0)*(.0358-.0230)/.5                          IPSC2930
     XMU22=.0728-(1.5-ELEK)*(.0728-.0368)/.5                          IPSC2940
     GO TO 530                                                        IPSC2950
480  XMU11=.0280-(ELEK-1.5)*(.0280-.0174)/.5                          IPSC2960
     XMU22=.0964-(2.0-ELEK)*(.0964-.0723)/.5                          IPSC2970
     GO TO 530                                                        IPSC2980
490  XMU11=.0174-(ELEK-2.0)*(.0174-.0099)/.5                          IPSC2990
     XMU22=.1100-(2.5-ELEK)*(.1100-.0964)/.5                          IPSC3000
     GO TO 530                                                        IPSC3010
500  XMU11=.0099-(ELEK-2.5)*(.0099-.0055)/.5                          IPSC3020
     XMU22=.1172-(3.0-ELEK)*(.1172-.1100)/.5                          IPSC3030
     GO TO 530                                                        IPSC3040
510  XMU11=.0055-(ELEK-3.0)*(.0055-.0004)/2.0                         IPSC3050
     XMU22=.1245-(5.0-ELEK)*(.1245-.1172)/2.0                         IPSC3060
     GO TO 530                                                        IPSC3070
520  XMU11=0.0                                                        IPSC3080
     XMU22=.1250                                                      IPSC3090
530  CONTINUE                                                         IPSC3100
     XLEKH=(XMU22+XMU11*XNU*(DEDNE/DEDNU)**.5)*XLGTH*XLGTH            IPSC3110
     SUMPRX=0.                                                        IPSC3120
     SUMPRY=0.                                                        IPSC3130
     SUMXIN=0.                                                        IPSC3140
     SUMYIN=0.                                                        IPSC3150
     SUMXZR=0.                                                        IPSC3160
     SUMYZR=0.                                                        IPSC3170
     XMM=1.                                                           IPSC3180
540  CONTINUE                                                         IPSC3190
     ALSUBM=XMM*3.14159*PANWID*.5/XLGTH                               IPSC3200
     XLAMDA=ESTIFF/(XLGTH*DEDNE)                                      IPSC3210
     HSIN=TANH(ALSUBM)/(SQRT(1.-TANH(ALSUBM)*TANH(ALSUBM)))          IPSC3220
     HCOS=           1./(SQRT(1.-TANH(ALSUBM)*TANH(ALSUBM)))          IPSC3230
     PT1=XNU*(1.+XNU)*HSIN                                            IPSC3240
     PT2=XNU*(1.-XNU)*HCOS*ALSUBM                                     IPSC3250
     PT3=  2.*HCOS+ALSUBM*HSIN                                        IPSC3260
     PT4=(3.+XNU)*(1.-XNU)*HSIN*HCOS                                  IPSC3270
     PT5=(1.-XNU)**2.*ALSUBM                                          IPSC3280
     PT6=2.*XMM*3.14159*XLAMDA*HCOS**2.                              IPSC3290
     PT7=XNU*(1.-XNU)*HSIN                                            IPSC3300
     PT8=XMM*3.14159*XLAMDA*HCOS                                      IPSC3310
     PT9=4./(XMM*3.14159)**5.                                        IPSC3320
     AM=PT9*(PT1-PT2-XMM*3.14159*XLAMDA*PT3)/(PT4-PT5+PT6)           IPSC3330
     BM=PT9*(PT7+PT8)/(PT4-PT5+PT6)                                  IPSC3340
     PT10=(XMM*3.14159/XLGTH)                                        IPSC3350
     PT11=PT10*PT10                                                  IPSC3360
     PARTX=PT11*(PT9+AM)*SIN(PT10*XLGTH/2.)                          IPSC3370
     PARTY=(PT11*AM+2.*BM*PT11)*SIN(PT10*XLGTH/2.)                   IPSC3380
     SUMPRX=SUMPRX+PARTX                                             IPSC3390
     SUMPRY=SUMPRY+PARTY                                             IPSC3400
     AMZERO=PT9*(PT1-PT2)/(PT4-PT5)                                  IPSC3410
     BMZERO=PT9*PT7/(PT4-PT5)                                        IPSC3420
     AMINFN=-PT9*PT3/(2.*HCOS*HCOS)                                  IPSC3430
     BMINFN=PT9/(2.*HCOS)                                            IPSC3440
     PARXIN=PT11*(PT9+AMINFN)*SIN(PT10*XLGTH/2.)                     IPSC3450
     PARYIN=(PT11*AMINFN+2.*BMINFN*PT11)*SIN(PT10*XLGTH/2.)          IPSC3460
     PARXZR=PT11*(PT9+AMZERO)*SIN(PT10*XLGTH/2.)                     IPSC3470
     PARYZR=(PT11*AMZERO+2.*BMZERO*PT11)*SIN(PT10*XLGTH/2.)          IPSC3480
     SUMXIN=SUMXIN+PARXIN                                            IPSC3490
     SUMYIN=SUMYIN+PARYIN                                            IPSC3500
     SUMXZR=SUMXZR+PARXZR                                            IPSC3510
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C-7

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      SUMYZR=SUMYZR+PARYZR
      IF(XMM.EQ.7.)GO TO 550                                    IPSC 3520
      XMM=XMM+2.                                                IPSC 3530
      GO TO 540                                                 IPSC 3540
  550 XTIMO=(XLGTH**4.)*(+SJMXX-XNU*SUMPXY)                     IPSC 3550
      TIMOIN=(XLGTH**4.)*(+SUMXIN-XNU*SUMYIN)                   IPSC 3560
      TIMOZR=(XLGTH**4.)*(+SUMXZR-XNU*SUMYZR)                   IPSC 3570
      PLAM=XLEKH+(.1250-XLEKH)*(XTIMO-TIMOIN)/(TIMOZR-TIMOIN)   IPSC 3580
  560 CONTINUE                                                  IPSC 3590
C---- MOMENTS FOR PRESSURE LOADS                                IPSC 3600
C---- BEAM WITH SIMPLE SUPPORTS                                 IPSC 3620
      DO 580 M=1,NTIME                                          IPSC 3630
  580 XMOM(M) = (PRESS(M)*XLGTH*(X(I) - DX/2.0)/2.0 - PRESS(M)* IPSC 3640
     1((X(I) - DX/2.0)**2)/2.0)*PANWID                          IPSC 3650
      IF(INDPLA.EQ.0)GO TO 560                                  IPSC 3660
      IF(XLGTH.GT.PANWID)GO TO 660                              IPSC 3670
      IF(DETNO.GT.0EONE)GO TO 660                               IPSC 3680
      DO 590 M=1,NTIME                                          IPSC 3590
      XMIDM=PRESS(M)*XLGTH*XLGTH*PANWID/8.                      IPSC 3700
  590 XMOM(M)=PLAM*PRESS(M)*PANWID*XMOM(M)/XMIDM                IPSC 3710
      DO 600 M=1,NTIME                                          IPSC 3720
  600 PRTMOM(I,M)=XMOM(M)                                       IPSC 3730
      GO TO 660                                                 IPSC 3740
C---- BEAM WITH FIXED SUPPORTS                                  IPSC 3750
      XX1=(XLGTH/2.)*(X(I)-(X(I)**2)/XLGTH-XLGTH/6.0)*PANWID    IPSC 3760
      DO 620 M=1,NTIME                                          IPSC 3770
  620 XMOM(M)=PRESS(M)*XX1                                      IPSC 3780
      GO TO 660                                                 IPSC 3790
C---- MOMENTS FOR POINT LOADS                                   IPSC 3800
  630 DO 650 K=1,NTIME                                          IPSC 3810
      IF(X(I).LT.ALEN) GO TO 640                                IPSC 3820
      XMOM(K) = PLOAD(K)*ALEN/2.0                               IPSC 3830
      GO TO 650                                                 IPSC 3840
  640 XMOM(K) = PLOAD(K)*(X(I)-DX/2.)/2.                        IPSC 3850
  650 CONTINUE                                                  IPSC 3860
  660 CONTINUE                                                  IPSC 3870
      KOUNTX = 0                                                IPSC 3880
      CALL ITIMOM(       C      , D      , NAREA , XMOM  , YBAR  ,  IPSC 3890
     1Y      , XI     , E      , NTIME  , A     , DX    , DY    ,  IPSC 3900
     2STRANE , THETAE , STRESE , YNA    , I     , INDTFD , NTCON ,  IPSC 3910
     3 NSECT , TICON )                                          IPSC 3920
      IF(INDELA.EQ.1) GO TO 1550                                IPSC 3930
      THETAC=0.                                                 IPSC 3940
      DO 670 J=1,NAREA                                          IPSC 3950
  670 CSTRAN(J)=0.0                                             IPSC 3960
      IF(ILOAD.EQ.1)GO TO 700                                   IPSC 3970
      DO 690 K1=1,NTIME                                         IPSC 3980
      WRITE(6,1820)K1                                           IPSC 3990
      WRITE(6,1830)                                             IPSC 4000
      DO 680  J=1,NAREA                                         IPSC 4010
      SUBA=A(J)*2.54*2.54                                       IPSC 4020
      SUBY=Y(J)*2.54                                            IPSC 4030
      SUBSTR=STRESE(K1,J)*6.8948/1000.                          IPSC 4040
      WRITE(6,1840)J,SUBA,SUBY,SUBSTR                           IPSC 4050
  680 CONTINUE                                                  IPSC 4060
  690 CONTINUE                                                  IPSC 4070
      GO TO 730                                                 IPSC 4080
  700 CONTINUE                                                  IPSC 4090
      DO 720 K1=1,NTIME                                         IPSC 4100
                                                                IPSC 4110
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            WRITE(6,1820)K1                                            IPSC4120
            WRITE(6,1850)                                              IPSC4130
            DO 710 J=1,NAREA                                           IPSC4140
 710    WRITE(6,1840)J,A(J),Y(J),STRESE(K1,J)                          IPSC4150
 720    CONTINUE                                                       IPSC4160
 730    CONTINUE                                                       IPSC4170
            DO 1540 KK=1,NCYCLE                                        IPSC4180
C                                                                      IPSC4190
C --- CYCLE LOOP                                                       IPSC4200
C                                                                      IPSC4210
            DO 1530 K1=1,NTIME                                         IPSC4220
C                                                                      IPSC4230
C --- TRAJECTORY STEP LOOP                                            IPSC4240
C                                                                      IPSC4250
            TIME1=TIME                                                 IPSC4260
            TIME =((KK - 1)*DXTIME(NTIME) + DXTIME(K1))/60.            IPSC4270
            IF(KK.EQ.1.AND.K1.EQ.1)GO TO 760                           IPSC4280
            IF(INDLOD.EQ.1) GO TO 740                                  IPSC4290
            THETAT(K1)=SAVTHE*PRESS(K1)*T(K1,1)*(TIME-TIME1)           IPSC4300
     1 /(SAVPRS*SAVTMP*TIMBER)+THETAE(I,K1)                            IPSC4310
            GO TO 750                                                  IPSC4320
 740    THETAT(K1)=SAVTHE*PLOAD(K1)*T(K1,1)*(TIME-TIME1)               IPSC4330
     1 /(SAVLOD*SAVTMP*TIMBER)+THETAE(I,K1)                            IPSC4340
 750    CONTINUE                                                       IPSC4350
            GO TO 780                                                  IPSC4360
 760    CONTINUE                                                       IPSC4370
            AYNAC=YNA(K1)                                              IPSC4380
            THETAT(K1)=2.*THETAE(I,K1)                                 IPSC4390
            DO 770 J=1,NAREA                                           IPSC4400
 770    STRESS(J)=STRESE(K1,J)                                         IPSC4410
 780    CONTINUE                                                       IPSC4420
            TIMBER=TIME-TIME1                                          IPSC4430
            FIRSTM=0.                                                  IPSC4440
 790    F2=0.                                                          IPSC4450
 800    CONTINUE                                                       IPSC4460
            XM1=0.0                                                    IPSC4470
            FBAL=0.                                                    IPSC4480
 810    TOTFOR=0.                                                      IPSC4490
            DO 1340 J=1,NAREA                                          IPSC4500
            ASTRAT(J) = THETAT(K1)*(AYNAC - Y(J))/DX                   IPSC4510
            IF(FBAL.EQ.0.)GO TO 820                                    IPSC4520
C                                                                      IPSC4530
C    8011                                                              IPSC4540
C                                                                      IPSC4550
 820    CONTINUE                                                       IPSC4560
C                                                                      IPSC4580
C                                                                      IPSC4590
C       ITTERATION FOR STRESS                                          IPSC4600
C                                                                      IPSC4610
C                                                                      IPSC4620
            SIGN=0.                                                    IPSC4630
            L=1                                                        IPSC4640
            STRES(L)=STRESS(J)                                         IPSC4650
            IF(IINTP.EQ.IEQNTP)GO TO 850                               IPSC4660
            IF(IEQNTP.EQ.0)GO TO 840                                   IPSC4670
            X3=((9./5.)*T(K1,J)-459.67)/1000.                          IPSC4680
            GO TO 860                                                  IPSC4690
 840    X3=((5./9.)*(T(K1,J)+459.67)/1000.)                           IPSC4700
            GO TO 860.                                                 IPSC4710
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C-9

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   850 X3=T(KL,J)/1000.                                          IPSC4720
   860 CONTINUE                                                  IPSC4730
       X5=1./X3                                                  IPSC4740
       X8=ALOG(X3)                                               IPSC4750
       X11=X5*X5                                                 IPSC4760
       X12=X5*X11                                                IPSC4770
       X31=X3*X3                                                 IPSC4780
       X32=X3*X31                                                IPSC4790
       X33=X8*X8                                                 IPSC4800
       X34=X8*X33                                                IPSC4810
   870 IF(HARDOP.EQ.2.)GO TO 1000                                IPSC4820
C                                                                IPSC4830
C                                                                IPSC4840
C      TIME HARDENING THEORY OF CREEP ACCUMULATION               IPSC4850
C                                                                IPSC4860
C                                                                IPSC4870
       IF(L.NE.1)GO TO 900                                       IPSC4880
       X4=TIME                                                   IPSC4890
       X4X=TIME1                                                 IPSC4900
       X6=ALOG(X4)                                               IPSC4910
       IF(TIME1.EQ.0.)GO TO 880                                  IPSC4920
       X6X=ALOG(X4X)                                             IPSC4930
       GO TO 890                                                 IPSC4940
   880 X6X=0.                                                    IPSC4950
   890 CONTINUE                                                  IPSC4960
       X27=X4*X4                                                 IPSC4970
       X27X=X4X*X4X                                              IPSC4980
       X28=X4*X27                                                IPSC4990
       X28X=X4X*X27X                                             IPSC5000
       X29=X6*X6                                                 IPSC5010
       X29X=X6X*X6X                                              IPSC5020
       X30=X6*X29                                                IPSC5030
       X30X=X6X*X29X                                             IPSC5040
       X36=X3*X6                                                 IPSC5050
       X36X=X3*X6X                                               IPSC5060
       X38=X4*X8                                                 IPSC5070
       X38X=X4X*X8                                               IPSC5080
       X40=X6*X8                                                 IPSC5090
       X40X=X6X*X8                                               IPSC5100
       X42=X5*X6                                                 IPSC5110
       X42X=X5*X6X                                               IPSC5120
       X45=X3*X4                                                 IPSC5130
       X45X=X3*X4X                                               IPSC5140
   900 CONTINUE                                                  IPSC5150
       IF(STRES(L).GT.0.)GO TO 910                               IPSC5160
       IF(STRES(L).EQ.0.)GO TO 970                               IPSC5170
       STRES(L)=ABS(STRES(L))                                    IPSC5180
       SIGN=1.0                                                  IPSC5190
   910 CONTINUE                                                  IPSC5200
       IF(IEONST.EQ.0.)GO TO 920                                 IPSC5210
       X2=STRES(L)/1000.                                         IPSC5220
       GO TO 930                                                 IPSC5230
   920 X2=STRES(L)*6.8948/1000.                                  IPSC5240
   930 CONTINUE                                                  IPSC5250
       LINEAR=0                                                  IPSC5260
       IF(X2.GT.1.)GO TO 940                                     IPSC5270
       IF(INDSTR.EQ.0)GO TO 940                                  IPSC5280
       X2=1.                                                     IPSC5290
       LINEAR=1                                                  IPSC5300
```

```
 940 CONTINUE                                                    IPSC5310
     X7=ALOG(X2)                                                 IPSC5320
     X9=X2*X2                                                    IPSC5330
     X10=X9*X2                                                   IPSC5340
     X13=X2*X3                                                   IPSC5350
     X14=X2/X3                                                   IPSC5360
     X15=X13*X13                                                 IPSC5370
     X16=X15*X13                                                 IPSC5380
     X17=X14*X14                                                 IPSC5390
     X18=X14*X17                                                 IPSC5400
     X19=X7*X7                                                   IPSC5410
     X20=X7*X19                                                  IPSC5420
     X21=X2*X8                                                   IPSC5430
     X22=X3*X7                                                   IPSC5440
     X23=X7*X8                                                   IPSC5450
     X24=X2*X3*X4                                                IPSC5460
     X24X=X2*X3*X4X                                              IPSC5470
     X25=X24*X24                                                 IPSC5480
     X25X=X24X*X24X                                              IPSC5490
     X26=X24*X25                                                 IPSC5500
     X26X=X24X*X25X                                              IPSC5510
     X35=X2*X6                                                   IPSC5520
     X35X=X2*X6X                                                 IPSC5530
     X37=X4*X7                                                   IPSC5540
     X37X=X4*X*X7                                                IPSC5550
     X39=X6*X7                                                   IPSC5560
     X39X=X6X*X7                                                 IPSC5570
     X41=X5*X7                                                   IPSC5580
     X43=X42*X7                                                  IPSC5590
     X43X=X42X*X7                                                IPSC5600
     X44=X2*X4                                                   IPSC5610
     X44X=X2*X4X                                                 IPSC5620
     TERM3=Z(2)*X2+Z(7)*X7+Z(9)*X9+Z(10)*X10+Z(13)*X13+Z(14)*X14 IPSC5630
    1+Z(15)*X15+Z(16)*X16+Z(17)*X17+Z(18)*X18+Z(19)*X19+Z(20)*X20IPSC5640
    2+Z(21)*X21+Z(22)*X22+Z(23)*X23+Z(41)*X41                    IPSC5650
     IF(TIME1.EQ.0.)GO TO 950                                    IPSC5660
     TERM2=Z(1)+Z(3)*X3+Z(4)*X4X+Z(5)*X5+Z(6)*X5X+Z(8)*X8+Z(11)*X11IPSC5670
    1+Z(12)*X12+Z(27)*X27X+Z(28)*X28X+Z(29)*X29X+Z(30)*X30X      IPSC5680
    2+Z(31)*X31+Z(32)*X32+Z(33)*X33+Z(34)*X34+Z(35)*X36X+Z(38)*X38XIPSC5690
    3+Z(40)*X40X+Z(42)*X42X+Z(45)*X45X                           IPSC5700
     FUNC1=TERM2+TERM3+Z(24)*X24+Z(25)*X25X+Z(26)*X26X+Z(35)*X35X IPSC5710
    1+Z(37)*X37X+Z(39)*X39X+Z(43)*X43X+Z(44)*X44X                IPSC5720
     FUNC1=EXP(FUNC1)/100.                                       IPSC5730
     GO TO 960                                                   IPSC5740
 950 CONTINUE                                                    IPSC5750
     FUNC1=0.                                                    IPSC5760
 960 CONTINUE                                                    IPSC5770
     TERM1=Z(1)+Z(3)*X3+Z(4)*X4+Z(5)*X5+Z(6)*X6+Z(8)*X8+Z(11)*X11IPSC5780
    1+Z(12)*X12+Z(27)*X27+Z(28)*X28+Z(29)*X29+Z(30)*X30+Z(31)*X31IPSC5790
    2+Z(32)*X32+Z(33)*X33+Z(34)*X34+Z(36)*X36+Z(38)*X38+Z(40)*X40IPSC5800
    3+Z(42)*X42+Z(45)*X45                                        IPSC5810
     FUNC=TERM1+TERM3+Z(24)*X24+Z(25)*X25+Z(26)*X26+Z(35)*X35    IPSC5820
    1+Z(37)*X37+Z(39)*X39+Z(43)*X43+Z(44)*X44                    IPSC5830
     FUNC=EXP(FUNC)/100.                                         IPSC5840
     IF(FUNC.GT.FUNC1)GO TO 980                                  IPSC5850
 970 EPSCRP=0.                                                   IPSC5860
     GO TO 990                                                   IPSC5870
 980 EPSCRP=FUNC-FUNC1                                           IPSC5880
     IF(LINEAR.EQ.0)GO TO 990                                    IPSC5890
```

```
      EPSCRP=EPSCRP*(STRES(L)/1000.)
 990  CONTINUE
1000  IF(HARDOP.EQ.1)GO TO 1150
      IF(I.EQ.6.AND.KK.EQ.50)GO TO 1010
      GO TO 1020
1010  WRITE(6,1860)J,L,STRES(L)
1020  CONTINUE
C
C
C     STRAIN HARDENING THEORY OF CREEP ACCUMULATION
C
C
      IF(STRES(L).GT.0.)GO TO 1030
      STRES(L)=ABS(STRES(L))
      SIGN=1.0
1030  CONTINUE
      IF(STRES(L).GT.10.)GO TO 1040
      DSTR2=0.
      GO TO 1150
1040  CONTINUE
      TEFF1=0.
      TEFF2=0.
      ACONST=0.
      BCONST=0.
      CCONST=0.
      FCONST=0.
      IF(IEONST.EQ.0.)GO TO 1050
      X2=STRES(L)/1000.
      GO TO 1060
1050  X2=STRES(L)*6.8948/1000.
1060  CONTINUE
      X7=ALOG(X2)
      X9=X2*X2
      X10=X9*X2
      X13=X2*X3
      X14=X2/X3
      X15=X13*X13
      X16=X15*X13
      X17=X14**X14
      X18=X14*X17
      X19=X7*X7
      X20=X7*X19
      X21=X2*X3
      X22=X3*X7
      X23=X7*X8
      X41=X5*X7
      TERM5=Z(1)+Z(2)*X2+Z(3)*X3+Z(5)*X5+Z(7)*X7+
     17(8)*X8+Z(9)*X9+Z(10)*X10+Z(11)*X11+Z(12)*X12+
     22(13)*X13+Z(14)*X14+Z(15)*X15+Z(16)*X16+Z(17)*X17+Z(18)*X18+
     32(19)*X19+Z(20)*X20+Z(21)*X21+Z(22)*X22+Z(23)*X23+Z(31)*X31+
     42(32)*X32+Z(33)*X33+Z(34)*X34+Z(41)*X41
      IF(CSTRAN(J).GT..0001)GO TO 1070
      X4=(TIME-TIME1)
      X6=ALOG(X4)
      X24=X2*X3*X4
      X25=X24*X24
      X26=X24*X25
      X27=X4*X4
      X28=X4*X27
```

Right margin line numbers:
IPSC5900
IPSC5910
IPSC5920
IPSC5930
IPSC5940
IPSC5950
IPSC5960
IPSC5970
IPSC5980
IPSC5990
IPSC6000
IPSC6010
IPSC6020
IPSC6030
IPSC6040
IPSC6050
IPSC6060
IPSC6070
IPSC6080
IPSC6090
IPSC6100
IPSC6110
IPSC6120
IPSC6130
IPSC6140
IPSC6150
IPSC6160
IPSC6170
IPSC6180
IPSC6190
IPSC6200
IPSC6210
IPSC6220
IPSC6230
IPSC6240
IPSC6250
IPSC6260
IPSC6270
IPSC6280
IPSC6290
IPSC6300
IPSC6310
IPSC6320
IPSC6330
IPSC6340
IPSC6350
IPSC6360
IPSC6370
IPSC6380
IPSC6390
IPSC6400
IPSC6410
IPSC6420
IPSC6430
IPSC6440
IPSC6450
IPSC6460
IPSC6470
IPSC6480

```
            X29=X6*X6                                                  IPSC6490
            X30=X6*X29                                                 IPSC6500
            X35=X2*X6                                                  IPSC6510
            X36=X3*X6                                                  IPSC6520
            X37=X4*X7                                                  IPSC6530
            X38=X4*X8                                                  IPSC6540
            X39=X6*X7                                                  IPSC6550
            X40=X6*X8                                                  IPSC6560
            X42=X5*X6                                                  IPSC6570
            X43=X42*X7                                                 IPSC6580
            X44=X2*X4                                                  IPSC6590
            X45=X3*X4                                                  IPSC6600
            TERM6=Z(4)*X4+Z(6)*X6+Z(24)*X24+Z(25)*X25+Z(26)*X26+Z(27)*X27+  IPSC6610
           1Z(28)*X28+Z(29)*X29+Z(30)*X30+Z(35)*X35+Z(36)*X36+Z(37)*X37+    IPSC6620
           2Z(38)*X38+Z(39)*X39+Z(40)*X40+Z(42)*X42+Z(43)*X43+Z(44)*X44+    IPSC6630
           3Z(45)*X45                                                  IPSC6640
            DSTR2=TERM5+TERM6                                          IPSC6650
            DSTR2=EXP(DSTR2)/100.                                      IPSC6660
            GO TO 1150                                                 IPSC6670
 1070 CONTINUE                                                         IPSC6680
            TEFF1=TMAX                                                 IPSC6690
            X4=TEFF1                                                   IPSC6700
            X6=ALOG(X4)                                                IPSC6710
            X24=X2*X3*X4                                               IPSC6720
            X25=X24*X24                                                IPSC6730
            X26=X24*X25                                                IPSC6740
            X27=X4*X4                                                  IPSC6750
            X28=X4*X27                                                 IPSC6760
            X29=X6*X6                                                  IPSC6770
            X30=X6*X29                                                 IPSC6780
            X35=X2*X6                                                  IPSC6790
            X36=X3*X6                                                  IPSC6800
            X37=X4*X7                                                  IPSC6810
            X38=X4*X8                                                  IPSC6820
            X39=X6*X7                                                  IPSC6830
            X40=X6*X8                                                  IPSC6840
            X42=X5*X6                                                  IPSC6850
            X43=X42*X7                                                 IPSC6860
            X44=X2*X4                                                  IPSC6870
            X45=X3*X4                                                  IPSC6880
            TERM6=Z(4)*X4+Z(6)*X6+Z(24)*X24+Z(25)*X25+Z(26)*X26+Z(27)*X27+  IPSC6890
           1Z(28)*X28+Z(29)*X29+Z(30)*X30+Z(35)*X35+Z(36)*X36+Z(37)*X37+    IPSC6900
           2Z(38)*X38+Z(39)*X39+Z(40)*X40+Z(42)*X42+Z(43)*X43+Z(44)*X44+    IPSC6910
           3Z(45)*X45                                                  IPSC6920
            EPS1= TERM5+TERM6                                          IPSC6930
            EPS1=EXP(EPS1)/100.                                        IPSC6940
            IF(EPS1.GT.CSTRAN(J))GO TO 1090                           IPSC6950
            TEFF2=TEFF1+1./60.                                         IPSC6960
            X4=TEFF2                                                   IPSC6970
            X6=ALOG(X4)                                                IPSC6980
            X24=X2*X3*X4                                               IPSC6990
            X25=X24*X24                                                IPSC7000
            X26=X24*X25                                                IPSC7010
            X27=X4*X4                                                  IPSC7020
            X28=X4*X27                                                 IPSC7030
            X29=X6*X6                                                  IPSC7040
            X30=X6*X29                                                 IPSC7050
            X35=X2*X6                                                  IPSC7060
            X36=X3*X6                                                  IPSC7070
```

```
      X37=X4*X7                                                    IPSC7080
      X38=X4*X8                                                    IPSC7090
      X39=X6*X7                                                    IPSC7100
      X40=X6*X8                                                    IPSC7110
      X42=X5*X6                                                    IPSC7120
      X43=X42*X7                                                   IPSC7130
      X44=X2*X4                                                    IPSC7140
      X45=X3*X4                                                    IPSC7150
      TERM6=Z(4)*X4+Z(6)*X6+Z(24)*X24+Z(25)*X25+Z(26)*X26+Z(27)*X27+ IPSC7160
     1Z(28)*X28+Z(29)*X29+Z(30)*X30+Z(35)*X35+Z(36)*X36+Z(37)*X37+  IPSC7170
     2Z(38)*X38+Z(39)*X39+Z(40)*X40+Z(42)*X42+Z(43)*X43+Z(44)*X44+  IPSC7180
     3Z(45)*X45                                                    IPSC7190
      EPS2= TERM5+TERM6                                            IPSC7200
      EPS2=EXP(EPS2)/100.                                          IPSC7210
      IF(EPS2.LE.EPS1)GO TO 1080                                   IPSC7220
      DSTR2=(EPS2-EPS1)*(TIME-TIME1)*60.                           IPSC7230
      BCONST=2.                                                    IPSC7240
      GO TO 1150                                                   IPSC7250
 1080 DSTR2=0.                                                     IPSC7260
      BCONST=3.                                                    IPSC7270
      GO TO 1150                                                   IPSC7280
 1090 TEFF2=TMAX*(CSTRAN(J)/EPS1)                                  IPSC7290
 1100 CONTINUE                                                     IPSC7300
      X4=TEFF2                                                     IPSC7310
      X6=ALOG(X4)                                                  IPSC7320
      X24=X2*X3*X4                                                 IPSC7330
      X25=X24*X24                                                  IPSC7340
      X26=X24*X25                                                  IPSC7350
      X27=X4*X4                                                    IPSC7360
      X28=X4*X27                                                   IPSC7370
      X29=X6*X6                                                    IPSC7380
      X30=X6*X29                                                   IPSC7390
      X35=X2*X6                                                    IPSC7400
      X36=X3*X6                                                    IPSC7410
      X37=X4*X7                                                    IPSC7420
      X38=X4*X8                                                    IPSC7430
      X39=X6*X7                                                    IPSC7440
      X40=X6*X8                                                    IPSC7450
      X42=X5*X6                                                    IPSC7460
      X43=X42*X7                                                   IPSC7470
      X44=X2*X4                                                    IPSC7480
      X45=X3*X4                                                    IPSC7490
      TERM6=Z(4)*X4+Z(6)*X6+Z(24)*X24+Z(25)*X25+Z(26)*X26+Z(27)*X27+ IPSC7500
     1Z(28)*X28+Z(29)*X29+Z(30)*X30+Z(35)*X35+Z(36)*X36+Z(37)*X37+  IPSC7510
     2Z(38)*X38+Z(39)*X39+Z(40)*X40+Z(42)*X42+Z(43)*X43+Z(44)*X44+  IPSC7520
     3Z(45)*X45                                                    IPSC7530
      EPS2= TERM5+TERM6                                            IPSC7540
      EPS2=EXP(EPS2)/100.                                          IPSC7550
      IF(EPS2.LE.EPS1)GO TO 1110                                   IPSC7560
      TEFF2=TEFF2*(CSTRAN(J)/EPS2)                                 IPSC7570
      GO TO 1100                                                   IPSC7580
 1110 IF(EPS2.GT.CSTRAN(J).AND.EPS1.GT.CSTRAN(J))GO TO 1120        IPSC7590
      SLOPE=(TEFF1-TEFF2)/(EPS1-EPS2)                              IPSC7600
      TEFF1=TEFF2                                                  IPSC7610
      EPS1=EPS2                                                    IPSC7620
      TEFF2=SLOPE*(CSTRAN(J)-EPS2)+TEFF2                           IPSC7630
      GO TO 1130                                                   IPSC7640
 1120 TEFF1=TEFF2                                                  IPSC7650
      EPS1=EPS2                                                    IPSC7660
```

```
      TEFF2=TEFF2*(CSTRAN(J)/EPS2)                                    TPSC7670
1130  CONTINUE                                                        TPSC7680
      X4=TEFF2                                                        TPSC7690
      X6=ALOG(X4)                                                     TPSC7700
      X24=X2*X3*X4                                                    TPSC7710
      X25=X24*X24                                                     TPSC7720
      X26=X24*X25                                                     TPSC7730
      X27=X4*X4                                                       TPSC7740
      X28=X4*X27                                                      TPSC7750
      X29=X6*X6                                                       TPSC7760
      X30=X6*X29                                                      TPSC7770
      X35=X2*X6                                                       TPSC7780
      X36=X3*X6                                                       TPSC7790
      X37=X4*X7                                                       TPSC7800
      X38=X4*X8                                                       TPSC7810
      X39=X6*X7                                                       TPSC7820
      X40=X6*X8                                                       TPSC7830
      X42=X5*X6                                                       TPSC7840
      X43=X42*X7                                                      TPSC7850
      X44=X2*X4                                                       TPSC7860
      X45=X3*X4                                                       TPSC7870
      TERM6=Z(4)*X4+Z(6)*X6+Z(24)*X24+Z(25)*X25+Z(26)*X26+Z(27)*X27+  TPSC7880
     1Z(28)*X28+Z(29)*X29+Z(30)*X30+Z(35)*X35+Z(36)*X36+Z(37)*X37+    TPSC7890
     2Z(38)*X38+Z(39)*X39+Z(40)*X40+Z(42)*X42+Z(43)*X43+Z(44)*X44+    TPSC7900
     3Z(45)*X45                                                       TPSC7910
      EPS2=TERM5+TERM6                                                TPSC7920
      EPS2=EXP(EPS2)/100.                                             TPSC7930
      IF(ABS((EPS2-CSTRAN(J))/CSTRAN(J)).LT..0001)GO TO 1140          TPSC7940
      GO TO 1110                                                      TPSC7950
1140  TEFF2=TEFF2+TIME-TIME1                                          TPSC7960
      X4=TEFF2                                                        TPSC7970
      X6=ALOG(X4)                                                     TPSC7980
      X24=X2*X3*X4                                                    TPSC7990
      X25=X24*X24                                                     TPSC8000
      X26=X24*X25                                                     TPSC8010
      X27=X4*X4                                                       TPSC8020
      X28=X4*X27                                                      TPSC8030
      X29=X6*X6                                                       TPSC8040
      X30=X6*X29                                                      TPSC8050
      X35=X2*X6                                                       TPSC8060
      X36=X3*X6                                                       TPSC8070
      X37=X4*X7                                                       TPSC8080
      X38=X4*X8                                                       TPSC8090
      X39=X6*X7                                                       TPSC8100
      X40=X6*X8                                                       TPSC8110
      X42=X5*X6                                                       TPSC8120
      X43=X42*X7                                                      TPSC8130
      X44=X2*X4                                                       TPSC8140
      X45=X3*X4                                                       TPSC8150
      TERM6=Z(4)*X4+Z(6)*X6+Z(24)*X24+Z(25)*X25+Z(26)*X26+Z(27)*X27+  TPSC8160
     1Z(28)*X28+Z(29)*X29+Z(30)*X30+Z(35)*X35+Z(36)*X36+Z(37)*X37+    TPSC8170
     2Z(38)*X38+Z(39)*X39+Z(40)*X40+Z(42)*X42+Z(43)*X43+Z(44)*X44+    TPSC8180
     3Z(45)*X45                                                       TPSC8190
      C3=    TERM5+TERM6                                              TPSC8200
      C3=EXP(C3)/100.                                                 TPSC8210
      DSTR2=C3-EPS2                                                   TPSC8220
1150  CONTINUE                                                        TPSC8230
      EPSCRP=DSTR2                                                    TPSC8240
1160  CONTINUE                                                        TPSC8250
```

```
       IF(SIGN.EQ.0.)GO TO 1170
       STRES(L)=-STRES(L)                                              IPSC8260
       SIGN=0.                                                         IPSC8270
       EPSCRP=-EPSCRP                                                  IPSC8280
 1170  CONTINUE                                                        IPSC8290
       SSTART=STRES(1)                                                 IPSC8300
       TOTCRP=EPSCRP+(STRES(L)+XESSTR(J))/E(K1,J)                      IPSC8310
C                                                                      IPSC8320
C   8015                                                               IPSC8330
C                                                                      IPSC8340
       IF(ASTRAT(J).EQ.TOTCRP)GO TO 1320                              IPSC8350
       CRATIO=TOTCRP/ASTRAT(J)                                         IPSC8360
       IF(ABS(CRATIO-1.000).LT..001)GO TO 1320                        IPSC8370
       IF(L.NE.1)GO TO 1270                                            IPSC8380
       L=2                                                             IPSC8390
       TSTR1=TOTCRP                                                    IPSC8400
       IF(STRES(1).NE.0.)GO TO 1200                                    IPSC8410
       IF(ASTRAT(J).GT.TOTCRP)GO TO 1190                              IPSC8420
 1180  STRES(2)=STRES(1)-100.                                          IPSC8430
       GO TO 870                                                       IPSC8440
 1190  STRES(2)=STRES(1)+100.                                          IPSC8450
       GO TO 870                                                       IPSC8460
 1200  IF(ASTRAT(J).NE.0.)GO TO 1210                                   IPSC8470
       IF(TOTCRP.LT.0.)GO TO 1190                                     IPSC8480
       GO TO 1180                                                      IPSC8490
 1210  IF(STRES(1).LT.0..AND.TOTCRP.GT.0..AND.ASTRAT(J).LT.TOTCRP)    IPSC8500
      1GO TO 1220                                                      IPSC8510
       IF(STRES(1).GT.0..AND.TOTCRP.LT.0..AND.ASTRAT(J).GT.TOTCRP)    IPSC8520
      1GO TO 1220                                                      IPSC8530
       GO TO 1230                                                      IPSC8540
 1220  STRES(2)=STRES(1)*2.                                            IPSC8550
       GO TO 870                                                       IPSC8560
 1230  CONTINUE                                                        IPSC8570
       IF(ABS(CRATIO).GT..1)GO TO 1250                                IPSC8580
       IF(ASTRAT(J).LT.0.)GO TO 1240                                   IPSC8590
       STRES(2)=STRES(1)+ABS(STRES(1))                                IPSC8600
       GO TO 1260                                                      IPSC8610
 1240  STRES(2)=STRES(1)-ABS(STRES(1))                                IPSC8620
       GO TO 1260                                                      IPSC8630
 1250  CONTINUE                                                        IPSC8640
       STRES(2)=STRES(1)/CRATIO                                        IPSC8650
 1260  CONTINUE                                                        IPSC8660
       GO TO 870                                                       IPSC8670
 1270  L=L+1                                                           IPSC8680
       IF(L.NE.20)GO TO 1280                                           IPSC8690
       WRITE(6,1870)I,J,KK,K1                                          IPSC8700
       GO TO 1320                                                      IPSC8710
 1280  CONTINUE                                                        IPSC8720
       TSTR2=TOTCRP                                                    IPSC8730
       IF(ASTRAT(J).EQ.0.)GO TO 1310                                   IPSC8740
       CRATIO=TOTCRP/ASTRAT(J)                                         IPSC8750
       IF(ABS(CRATIO-1.000).LT..001)GO TO 1290                        IPSC8760
       GO TO 1300                                                      IPSC8770
 1290  L=L-1                                                           IPSC8780
       GO TO 1320                                                      IPSC8790
 1300  CONTINUE                                                        IPSC8800
       SLOPE=(STRES(L-1)-STRES(L-2))/(TSTR2-TSTR1)                     IPSC8810
       STRES(L)=STRES(L-1)+(ASTRAT(J)-TSTR2)*SLOPE                     IPSC8820
       TSTR1=TSTR2                                                     IPSC8830
                                                                       IPSC8840
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           GO TO 870
1310  SLOPE=(STRES(L-1)-STRES(L-2))/(TSTR2-TSTR1)                              IPSC8850
      STRES(L)=STRES(L-1)-TSTR2*SLOPE                                          IPSC8860
      IF(ABS(STRES(L)/STRES(L-1)-1.00).LT..001)GO TO 1320                      IPSC8870
      IF(ABS(STRES(L)/STRES(L-2)-1.00).LT..001)GO TO 1320                      IPSC8880
      TSTR1=TSTR2                                                              IPSC8890
      GO TO 870                                                               IPSC8900
1320  CONTINUE                                                                IPSC8910
      STRESS(J)=STRES(L)                                                      IPSC8920
      FORC(J) = STRESS(J)*A(J)                                                IPSC8930
1340  TOTFOR = TOTFOR + FORC(J)                                              IPSC8940
C                                                                            IPSC8950
C     8010                                                                   IPSC8960
C                                                                            IPSC8970
      IF(FBAL.NE.0.)GO TO 1360                                               IPSC8980
      IF(TOTFOR.LT.0.0.AND.F2.GT.0.0) GO TO 1350                             IPSC8990
      IF(TOTFOR.GT.0.0.AND.F2.LT.0.0) GO TO 1350                             IPSC9000
      IF(ABS(TOTFOR).LT..001) GO TO 1380                                     IPSC9010
      Y2 = AYNAC                                                             IPSC9020
      IF(TOTFOR.LT.0.0) AYNAC = AYNAC + DY                                   IPSC9030
      IF(TOTFOR.GT.0.0) AYNAC = AYNAC - DY                                   IPSC9040
      F2 = TOTFOR                                                            IPSC9050
      GO TO 800                                                              IPSC9060
1350  CONTINUE                                                               IPSC9070
      AYNAC = AYNAC - (ABS(TOTFOR)*(AYNAC - Y2))/(ABS(TOTFOR) + ABS(F2))     IPSC9080
      FBAL=1.                                                                IPSC9090
      TOTFOR=0.                                                              IPSC9100
      GO TO 810                                                              IPSC9110
1360  CONTINUE                                                               IPSC9120
      DO 1370 J=1,NAREA                                                      IPSC9130
      ASTRAT(J) = THETAT(K1)*(AYNAC - Y(J))/DX                              IPSC9140
1370  CONTINUE                                                               IPSC9150
      TOTFOR = 0.0                                                           IPSC9160
1380  DO 1390 J=1,NAREA                                                      IPSC9170
      FORC(J) = STRESS(J)*A(J)                                              IPSC9180
      TOTFOR = TOTFOR + FORC(J)                                             IPSC9190
      XM1 = XM1 + ABS(FORC(J)*(AYNAC - Y(J)))                               IPSC9200
C                                                                            IPSC9210
C     8013                                                                   IPSC9220
C                                                                            IPSC9230
1390  CONTINUE                                                               IPSC9240
      TOL1 = ABS(XM1 - XMOM(K1))/XMOM(K1)                                   IPSC9250
C                                                                            IPSC9260
C     8006                                                                   IPSC9270
C                                                                            IPSC9280
      IF(TOL1.LT..001) GO TO 1410                                           IPSC9290
      IF(FIRSTM.NE.0.)GO TO 1400                                            IPSC9300
      FIRSTM=1.                                                              IPSC9310
      XM10=XM1                                                               IPSC9320
      THAT1=THETAT(K1)                                                      IPSC9330
      THETAT(K1)=THETAT(K1)*(XMOM(K1)/XM1)                                  IPSC9340
      GO TO 790                                                              IPSC9350
1400  CONTINUE                                                               IPSC9360
      THAT2=THETAT(K1)                                                      IPSC9370
      TOL1=ABS(XM1-XMOM(K1))/XMOM(K1)                                       IPSC9380
      IF(TOL1.LT..001)GO TO 1410                                            IPSC9390
      SLOPEM=(THAT2-THAT1)/(XM1-XM10)                                       IPSC9400
      THETAT(K1)=SLOPEM*(XMOM(K1)-XM1)+THAT2                                IPSC9410
C                                                                            IPSC9420
                                                                            IPSC9430
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C   4007
C
        THATI=THAT2                                                    IPSC9440
        XMIO=XMI                                                       IPSC9450
        GO TO 790                                                      IPSC9450
1410 CONTINUE                                                          IPSC9470
        SAVTHE=THETAT(KL)-THETAE(I,KL)                                 IPSC9480
        SAVTMP=T(K1,1)                                                 IPSC9490
        IF(INDLOD.EQ.1) GO TO 1420                                     IPSC9500
        SAVPRS=PRESS(K1)                                               TPSC9510
        GO TO 1430                                                     IPSC9520
1420 SAVLOD=PLOAD(K1)                                                  IPSC9530
1430 CONTINUE                                                          IPSC9540
        DO 1440 J=1,NAREA                                              TPSC9550
        RESSTR(J)=STRESE(K1,J)-STRESS(J)                              IPSC9560
1440 CONTINUE                                                          IPSC9570
        THETAC=THETAC+THETAT(KL)-THETAE(I,KL)                          IPSC9580
        DO 1450 J=1,NAREA                                             TPSC9590
1450 CSTRAN(J)=THETAC*(AYNAC-Y(J))/DX                                  IPSC9600
     1-RESSTR(J)/E(K1,J)                                              TPSC9610
        IF(INCYC.EQ.0) GO TO 1460                                      IPSC9620
        IF(KK.NE.1)GO TO 1460                                         TPSC9630
        THET(I,K1)=THETAC                                              IPSC9640
1460 IF(K).NE.NTIME) GO TO 1530                                       TPSC9650
        DO 1470 N=1,NUMCYC                                            IPSC9660
        NUMC1 = N                                                      TPSC9670
        IF(KK.EQ.KCYCLE(N)) GO TO 1480                                 IPSC9680
1470 CONTINUE                                                          IPSC9690
        GO TO 1500                                                     IPSC9700
1480 DO 1490 J=1,NAREA                                                 IPSC9710
        PSTRAN(I,J,NUMC1)=CSTRAN(J)*100.                               IPSC9720
        RESP(I,J,NUMC1)=RESSTR(J)                                      IPSC9730
1490 CONTINUE                                                          IPSC9740
1500 CONTINUE                                                          TPSC9750
        DO 1510 N=1,NUMCYC                                             IPSC9760
        NUMC2 = N                                                      IPSC9770
1510 IF(KK.EQ.KCYCLE(N)) GO TO 1520                                    IPSC9780
        GO TO 1530                                                     TPSC9790
1520 THETAP(I,NUMC2) = THETAC                                          IPSC9800
1530 CONTINUE                                                          TPSC9810
1540 CONTINUE                                                          IPSC9820
1550 CONTINUE                                                          IPSC9830
        IF(INDELA.EQ.1) GO TO 1610                                     IPSC9840
        DO 1600 L1=1,NUMCYC                                           IPSC9850
        NMIN2=NSTAT-2                                                  IPSC9860
        DO 1580 L2=1,NMIN2                                             IPSC9870
        SUM1=0.0                                                       TPSC9880
        SUM2=0.0                                                       IPSC9890
        SUM3=0.                                                        IPSC9900
        IPRIL2=IPRINT(L2)                                             TPSC9910
        DO 1560 N1=L,IPRIL2                                            TPSC9920
        THETAX=(THETAP(N1,L1)+THETAP(N1+1,L1))*X(N1)/2.0               TPSC9930
        SUM1=SUM1+THETAX                                               TPSC9940
1560 CONTINUE                                                          IPSC9950
        IPRL21=IPRIL2+2                                                IPSC9960
        DO 1570 N2=IPRL21,NSTAT                                        TPSC9970
1570 SUM2=SUM2+THETAP(N2,L1)                                           IPSC9980
        DFFL(L1,L2)=SUM1+SUM2*      X(L2)+      X(L2)*THETAP(L2+1,L1)/2.   TPSC9990
1580 CONTINUE                                                          IPSC   10
                                                                      IPSC   20
                                                                      IPSC   30
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         NMIN1=NSTAT-1                                              IPSC   40
         DO 1590 N1=1,NMIN1                                         IPSC   50
         THETAY=(THETAP(N1,L1)+THETAP(N1+1,L1))*X(N1)/2.0           IPSC   60
         SUM3=SUM3+THETAY                                           IPSC   70
 1590 CONTINUE                                                      IPSC   80
         DEFL(L1,NSTAT-1)=SUM3+THETAP(NSTAT,L1)*X(NSTAT-1)/2.0      IPSC   90
         DEFL(L1,NSTAT)=SUM3+THETAP(NSTAT,L1)*X(NSTAT)/2.0          IPSC  100
 1600 CONTINUE                                                      IPSC  110
 1610 CONTINUE                                                      IPSC  120
         DO 1660 L1=1,NTIME                                         IPSC  130
         NMIN2=NSTAT-2                                              IPSC  140
         DO 1640 L2=1,NMIN2                                         IPSC  150
         SUM4=0.                                                    IPSC  160
         SUM5=0.                                                    IPSC  170
         SUM6=0.                                                    IPSC  180
         IPRIL2=IPRINT(L2)                                          IPSC  190
         DO 1620 N1=1,IPRIL2                                        IPSC  200
         ETHETA = ( THETAE(N1,L1) + THETAE(N1+1,L1))*X(N1)/2.0      IPSC  210
         SUM4=SUM4+ETHETA                                           IPSC  220
 1620 CONTINUE                                                      IPSC  230
         IPRL21=IPRIL2+2                                            IPSC  240
         DO 1630 N2=IPRL21,NSTAT                                    IPSC  250
 1630 SUM5=SUM5+THETAE(N2,L1)                                       IPSC  260
         DEFLE(L1,L2)=SUM4+SUM5*      X(L2)+      X(L2)*THETAE(L2+1,L1)/2.  IPSC  270
 1640 CONTINUE                                                      IPSC  280
         NMIN1=NSTAT-1                                              IPSC  290
         DO 1650 N1=1,NMIN1                                         IPSC  300
         THETAY=(THETAE(N1,L1)+THETAE(N1+1,L1))*X(N1)/2.            IPSC  310
         SUM6=SUM6+THETAY                                           IPSC  320
 1650 CONTINUE                                                      IPSC  330
         DEFLE(L1,NSTAT-1)=SUM6+THETAE(NSTAT,L1)*X(NSTAT-1)/2.      IPSC  340
         DEFLE(L1,NSTAT)=SUM6+ THETAE(NSTAT,L1)*X(NSTAT)/2.         IPSC  350
 1660 CONTINUE                                                      IPSC  360
         IF(INCYC.EQ.0)GO TO 1720                                   IPSC  370
         DO 1710 L1=1,NTIME                                         IPSC  380
         NMIN2=NSTAT-2                                              IPSC  390
         DO 1690 L2=1,NMIN2                                         IPSC  400
         SUM7=0.0                                                   IPSC  410
         SUM8=0.0                                                   IPSC  420
         SUM9=0.0                                                   IPSC  430
         IPRIL2=IPRINT(L2)                                          IPSC  440
         DO 1670 N1=1,IPRIL2                                        IPSC  450
         THETAX=(THET(N1,L1)+THET(N1+1,L1))*X(N1)/2.0               IPSC  460
         SUM7=SUM7+THETAX                                           IPSC  470
 1670 CONTINUE                                                      IPSC  480
         IPRL21=IPRIL2+2                                            IPSC  490
         DO 1680 N2=IPRL21,NSTAT                                    IPSC  500
 1680 SUM8=SUM8+THET(N2,L1)                                         IPSC  510
         DEFLIN(L1,L2)=SUM7+SUM8*      X(L2)+      X(L2)*THET(L2+1,L1)/2.  IPSC  520
 1690 CONTINUE                                                      IPSC  530
         NMIN1=NSTAT-1                                              IPSC  540
         DO 1700 N1=1,NMIN1                                         IPSC  550
         THETAY=(THET(N1,L1)+THET(N1+1,L1))*X(N1)/2.0               IPSC  560
         SUM9=SUM9+THETAY                                           IPSC  570
 1700 CONTINUE                                                      IPSC  580
         DEFLIN(L1,NSTAT-1)=SUM9+THET(NSTAT,L1)*X(NSTAT-1)/2.0      IPSC  590
         DEFLIN(L1,NSTAT)=SUM9+THET(NSTAT,L1)*X(NSTAT)/2.0          IPSC  600
 1710 CONTINUE                                                      IPSC  610
 1720 CONTINUE                                                      IPSC  620
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      IF(IDIMEN.EQ.1)GO TO 1730                                                       IPSC  630)
      DEPTH=DEPTH      *2.540005                                                      IPSC  640)
      PITCH=PITCH      *2.540005                                                      IPSC  650)
      FLAT=FLAT        *2.540005                                                      IPSC  660)
      EDGE=EDGE        *2.540005                                                      IPSC  670)
      TS=TS            *2.540005                                                      IPSC  680)
      TC=TC            *2.540005                                                      IPSC  690)
      TR=TR            *2.540005                                                      IPSC  700)
      XLGTH=XLGTH      *2.540005                                                      IPSC  710)
      RIBFLG=RIBFLG    *2.540005                                                      IPSC  720)
      ZPNED1=ZPNED1    *2.540005                                                      IPSC  730)
      ZPNED2=ZPNED2    *2.540005                                                      IPSC  740)
      CZEE=CZEE        *2.540005                                                      IPSC  750)
      ZEESF1=ZEESF1    *2.540005                                                      IPSC  760)
      ZEEFF=ZEEFF      *2.540005                                                      IPSC  770)
      ZEEFF1=ZEEFF1    *2.540005                                                      IPSC  780)
      BWID=BWID        *2.540005                                                      IPSC  790)
      BDEP=BDEP        *2.540005                                                      IPSC  800)
      BRAD=BRAD        *2.540005                                                      IPSC  810)
      ALEN=ALEN        *2.540005                                                      IPSC  820)
      PANWID=PANWID    *2.540005                                                      IPSC  830)
      ZEESF=ZEESF      *2.540005                                                      IPSC  840)
      ESTIFF=ESTIFF*(2.540005**4.)                                                    IPSC  850)
 1730 CONTINUE                                                                        IPSC  860)
      CALL OUTPUT(     INDSED   , TS      , TR      , NRIB    , PITCH ,               IPSC  870)
     1RIBFLG , DEPTH   , TC      , NCOR    , FLAT    , EDGE    , PHICUR ,             IPSC  880)
     2TZEE    , NZEE    , ZPNED1  , ZPNED2  , ZEESF   , ZEESF1  , ZEEFF ,             IPSC  890)
     3ZEEFF1 , XLGTH   , INDRD   , BRAD    , BWID    , INDLOO  , INDSUP ,             IPSC  900)
     4ALEN   , DXTIME  , PRESS   , TEMP    , XPRINT  , NTIME   , NSTAT ,              IPSC  910)
     5DEFLE  , NUMCYC  , KCYCLE  , DEFL    , NAREA   , Y       , RESP ,               IPSC  920)
     6AM1,AM2,AM3,AM4,AM5,INDELA,PSTRAN,PLOAD,                                        IPSC  930)
     7 XI    , YBAR   , Z     , PANWID, DEFLIN  , INCYC ,                             IPSC  940)
     8ITIME   , IEQNTP , IINTP   , IDIMEN  , ILOAD , IEQNST)                          IPSC  950)
 1740 LOOP = LOOP + 1                                                                 IPSC  960)
      IF(LOOP.LT.NEWCAS) GO TO 10                                                     IPSC  970)
 1760 FORMAT(5A10)                                                                    IPSC  990)
 1770 FORMAT(1H1,////,50X,4HCASE,I4,9H ANALYSIS,/,                                    IPSC1000)
     148X,22HELASTIC STRESSES AT X=,F7.3,//)                                          IPSC1010)
 1780 FORMAT(40H ERROR IN TABLE-LOOKUP ROUTINE AT XIN = ,E15.3)                       IPSC1020)
 1790 FORMAT(40H ERROR IN TABLE-LOOKUP ROUTINE AT XIN = ,E15.4)                       IPSC1030)
 1800 FORMAT(40H ERROR IN TABLE-LOOKUP ROUTINE AT TIN = ,E15.5)                       IPSC1040)
 1820 FORMAT(///,48X,21HTRAJECTORY TIME STEP ,I2,/)                                   IPSC1060)
 1830 FORMAT(30X,1HJ,15X,11HAREA(SQ.CM),13X,5HY(CM),14X,11HSTRESS(MPA)/)              IPSC1070)
 1840 FORMAT(28X,I5,5X,3E20.5)                                                        IPSC1080)
 1850 FORMAT(30X,1HJ,15X,11HAREA(SQ.IN),13X,5HY(IN),14X,11HSTRESS(PSI)/)              IPSC1090)
 1860 FORMAT(5H 9003,10X,2I5,E15.5)                                                   IPSC1100)
 1870 FORMAT(65H WARNING - TWENTY ITERATIONS ON STRESS IN THE HARDENING               IPSC1110)
     1 ROUTINE.,/14H BEAM STATION ,I2,7X,11H SECTION(J),                             IPSC1120)
     2I2,7X,7H CYCLE ,I3,7X,6H STEP ,I2/42H ANALYSIS PROCEEDING WITH STR             IPSC1130)
     3ESS UNCHANGED,/)                                                                IPSC1140)
      END                                                                             
      SUBROUTINE GEOM(   INDGEO   , DEPTH   , TR      , NRIB    , PITCH ,             GEOM  10
     1RIBFLG , TS      , TC      , NCOR    , EDGE    , PHICUR  , FLAT  ,              GEOM  20
     2TZEE    , NZEE    , ZPNED1  , ZPNED2  , ZEEFF1  , ZEESF1  , ZEEFF ,            GEOM  30
     3ZEESF , A       , Y       , DY      , PANWID  ,                                GEOM  40
     4 NSECT , SEC , S )                                                             GEOM  50
C                                                                                     GEOM  60
C                                                                                     GEOM  70
C---- THIS SUBROUTINE DIVIDES THE TPS CROSS SECTION INTO DESCRETE                     GEOM  80
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C       ELEMENTS AND ASSIGNS Y(J) CENTROID LOCATIONS AND AREAS TO        GEOM   90
C       EACH ELEMENT.                                                    GEOM  100
C                                                                        GEOM  110
C                                                                        GEOM  120
        DIMENSION A(50) , Y(50)                                          GEOM  130
        COMMON PLANUM,PRIMUM,INDGEO                                      GEOM  140
        DATA RAD/57.295//95/                                            GEOM  150
        NSECT2=NSECT-1                                                   GEOM  160
        NSECT3=NSECT-2                                                   GEOM  170
        NSECT4=NSECT-4                                                   GEOM  180
        NSECT5=NSECT-3                                                   GEOM  190
        GO TO (10 ,40 ,80 ,230),INDGEO                                   GEOM  200
C                                                                        GEOM  210
C  --- CALCULATION OF RIB SECTION AREAS AND Y LOCATIONS; INDGEO = 1      GEOM  220
C                                                                        GEOM  230
   10   DY= (DEPTH-TS)/(SEC-1.)                                          GEOM  240
        A(1)=((DEPTH-TS)/(SEC-1.))*TR*NRIB                              GEOM  250
        DO 20   J=2,NSECT2                                               GEOM  260
   20   A(J) = A(J - 1)                                                  GEOM  270
        A(NSECT)=TS*((NRIB-1)*PITCH +2.0*RIBFLG)                         GEOM  280
        DO 30   J=1,NSECT2                                               GEOM  290
   30   Y(J) = (2.0*J - 1.0)*DY/2.0                                      GEOM  300
        Y(NSECT)=DEPTH-TS/2.0                                            GEOM  310
        RETURN                                                           GEOM  320
C                                                                        GEOM  330
C  --- CALCULATION OF CORRUGATED SECTION AREAS AND Y LOCATIONS; INDGEO = GEOM  340
C                                                                        GEOM  350
   40   DY= (DEPTH-TS-2.*TC)/(SEC-3.)                                    GEOM  360
        Y(1) = TC/2.0                                                    GEOM  370
        DO 50   J=2,NSECT3                                               GEOM  380
   50   Y(J) = TC + (J - 2)*DY + DY/2.0                                  GEOM  390
        Y(NSECT2)=Y(NSECT3)+TC/2.0+DY/2.0                               GEOM  400
        Y(NSECT)=DEPTH-TS/2.0                                            GEOM  410
        S=PITCH - 2.0*((Y(NSECT2)-Y(1))*(TAN(PHICOR /RAD)))-FLAT        GEOM  420
        IF(S.GE.0.0) GO TO 60                                            GEOM  430
        WRITE ( 6,240 )                                                  GEOM  440
        RETURN                                                           GEOM  450
   60   A(1) = S*NCOR*TC                                                 GEOM  460
        DO 70   J=2,NSECT3                                               GEOM  470
   70   A(J)=(DY/COS(PHICOR/RAD))*TC*NCOR*2.0                           GEOM  480
        A(NSECT2)= (NCOR*FLAT + 2.0*EDGE)*TC                            GEOM  490
        A(NSECT)= PANWID*TS                                             GEOM  500
        RETURN                                                           GEOM  510
C                                                                        GEOM  520
C  --- CALCULATION OF Z SECTION AREAS AND Y LOCATIONS;   INDGEO = 3      GEOM  530
C                                                                        GEOM  540
   80   DY= (DEPTH - TS - 2.0*TZEE)/(SEC-5.)                            GEOM  550
        Y(1) = TZEE/2.0                                                 GEOM  560
        DO 90   I=2,NSECT4                                               GEOM  570
   90   Y(I) = TZEE + (I - 2)*DY + DY/2.0                               GEOM  580
        IF(ZEEFF1.LE.TZEE) GO TO 120                                     GEOM  590
        DO 100   I=2,NSECT                                               GEOM  600
        IF((Y(I) + DY/2.0).GT.ZEEFF1) GO TO 110                        GEOM  610
  100   CONTINUE                                                         GEOM  620
  110   IHGT1 = I - 1                                                    GEOM  630
        H47 = ZEEFF1 - Y(I - 1) - DY/2.0                               GEOM  640
        Y(NSECT5) = ZEEFF1 -H47/2.0                                     GEOM  650
        A(NSECT5) = H47*NZEE*TZEE                                       GEOM  660
        GO TO 130                                                        GEOM  670
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C-21

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 120  Y(NSECT5) = 0.0                                                          GEOM 680
      A(NSECT5) = 0.0                                                          GEOM 690
 130  IF(ZEESF1.LE.TZEE) GO TO 150                                            GEOM 700
      DO 140 J=2,NSECT                                                         GEOM 710
      DEPTH1 = DEPTH - TS - ZEESF1                                             GEOM 720
      IF((Y(J) + DY/2.0).GT.DEPTH1) GO TO 150                                  GEOM 730
 140  CONTINUE                                                                 GEOM 740
 150  IHGT2 = J + 1                                                            GEOM 750
      H48 = Y(J) + DY/2.0 - DEPTH1                                             GEOM 760
      Y(NSECT3)= DEPTH1 + H48/2.0                                              GEOM 770
      A(NSECT3)= H48*NZEE*TZEE                                                 GEOM 780
      GO TO 170                                                                GEOM 790
 160  Y(NSECT3) = 0.0                                                          GEOM 800
      A(NSECT3) = 0.0                                                          GEOM 810
 170  Y(NSECT2) = DEPTH -TS -TZEE/2.0                                          GEOM 820
      Y(NSECT) = DEPTH - TS/2.0                                                GEOM 830
      A(1) = TZEE*ZEEFF*NZEE                                                   GEOM 840
      DO 180 K=2,NSECT4                                                        GEOM 850
 180  A(K) = DY*NZEE*TZEE                                                      GEOM 860
      IF(ZEEFF1.LE.TZEE) GO TO 200                                            GEOM 870
      DO 190 L=2,IHGT1                                                         GEOM 880
 190  A(L) = A(L) + DY*NZEE*TZEE                                               GEOM 890
 200  CONTINUE                                                                 GEOM 900
      IF(ZEESF1.EQ.0.0.OR.ZEESF1.LE.TZEE) GO TO 220                           GEOM 910
      DO 210 M=IHGT2,NSECT4                                                    GEOM 920
 210  A(M) = A(M) + DY*NZEE*TZEE                                               GEOM 930
 220  CONTINUE                                                                 GEOM 940
      A(NSECT2)= NZEE*ZEESF*TZEE                                               GEOM 950
      A(NSECT) = PANWID * TS                                                   GEOM 960
 230  CONTINUE                                                                 GEOM 970
      RETURN                                                                   GEOM 980
 240  FORMAT(50H CORRUGATION INPUT DATA YIELDS A NEGATIVE S LENGTH)           GEOM 990
      END
      SUBROUTINE TBLKP(T, IEX, XIN, YIN, Z, IE)                               TBLK   10
      DIMENSION T(1)                                                          TBLK   20
      COMMON PLAMOM,PRTMOM,INDPLA                                             TBLK   30
      I = IABS(IEX)                                                           TBLK   40
      IE = 0                                                                  TBLK   50
      NX = T(I+2)                                                             TBLK   60
      NY = T(I+3)                                                             TBLK   70
C---- INDEPENDENT VARIABLE, X TABLE LOOK-UP                                   TBLK   80
      LL = 5                                                                  TBLK   90
      LU = NX + 4                                                             TBLK  100
      LLS = T(I)                                                             TBLK  110
      VAR = XIN                                                               TBLK  120
      NRTN= 0                                                                 TBLK  130
      GO TO 50                                                                TBLK  140
  10  T(I) = LL                                                               TBLK  150
      IF (NY.GT.0) GO TO 20                                                   TBLK  160
      LZ = LL + NX                                                            TBLK  170
      Z = FRACT*(T(LZ+1) - T(LZ)) + T(LZ)                                     TBLK  180
      GO TO 190                                                               TBLK  190
C---- INDEPENDENT VARIABLE, Y TABLE LOOK-UP -- BIVARIATE                      TBLK  200
  20  LX = LL - 4                                                             TBLK  210
      FRX = FRACT                                                             TBLK  220
      LL = NX + 5                                                             TBLK  230
      LU = NX + NY + 4                                                        TBLK  240
      LLS = T(I+1)                                                           TBLK  250
      VAR = YIN                                                               TBLK  260
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      NRTN = 1
      GO TO 50
   30 T(I+1) = LL
C---- INTERPOLATION
      LZ = LL + NY * LX
      IF(FRX.EQ.1.) GO TO 40
      Z1 =  FRX * (T(LZ+NY)- T(LZ))+ T(LZ)
      LZ = LZ +1
      Z2 =  FRX * (T(LZ+NY)- T(LZ))+ T(LZ)
      Z  = FRACT* (Z2 - Z1) + Z1
      GO TO 190
   40 Z  = FRACT* (T(LZ+NY+1) - T(LZ+NY)) +  T(LZ+NY)
      GO TO 190
C---- BASIC SEARCH ROUTINE USING HALVING TECHNIQUE
   50 CONTINUE
C---- TEST IF INDEPENDENT VARIABLE EXCEEDS BOUNDS
      IF (VAR.LE.T(LU)) GO TO 60
      LL = LU - 1
      IF (IEX.GT.0) VAR = T(LU)
      GO TO 70
   60 IF (VAR.GE.T(LL)) GO TO 80
      IF (IEX.GT.0) VAR = T(LL)
   70 LE = 1
      GO TO 180
C---- TEST IF SAVED INDEX IS WITHIN TABLE BOUNDS
   80 LLS = MAXO(MINO(LLS,LU),LL)
      IF (LLS.GT.LL) LLS = LLS-1
      LK = MINO(LLS+2,LU)
      IF (VAR-T(LLS)) 120,110,90
   90 IF (VAR-T(LLS+1)) 110,110,100
  100 IF (LLS.EQ.LK) GO TO 130
      LLS = LLS+1
      GO TO 90
  110 LL = LLS
      GO TO 180
  120 LU = LLS
      GO TO 140
  130 LL = LLS+1
  140 IF (LU-LL.EQ.1) GO TO 180
      MID = (LU + LL)/2.
      D   = VAR - T(MID)
      IF (D) 150,170,160
  150 LU = MID
      GO TO 140
  160 LL = MID
      GO TO 140
  170 LL = MID
  180 CONTINUE
      FRACT =(VAR - T(LL))/ (T(LL+1) - T(LL))
      IF (NRTN) 10,10,30
  190 RETURN
      END
      SUBROUTINE ITMOM(C       , D    , NAREA , XMOM   , YBAR
     1Y     , XI    , E    , NTIME ; A     , DX     , DY
     2STRANE , THETAE , STRESE , YNA   , I     , INDTED , NICON
     3 NSECT , ITCON )
      DIMENSION C(4)     , D(4)     , XMOM(10) , Y(50)
     1          YNA(10)  , A(60)    , FORCEE(60)
      DIMENSION STRESE(10,60) , STRANE(10,60) , E(10,60)
```

```
IBLK 270
IBLK 280
IBLK 290
IBLK 300
IBLK 310
IBLK 320
IBLK 330
IBLK 340
IBLK 350
IBLK 360
IBLK 370
IBLK 380
IBLK 390
IBLK 400
IBLK 410
IBLK 420
IBLK 430
IBLK 440
IBLK 450
IBLK 460
IBLK 470
IBLK 480
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IBLK 500
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IBLK 670
IBLK 680
IBLK 690
IBLK 700
IBLK 710
IBLK 720
IBLK 730
IBLK 740
IBLK 750
IBLK 760
IBLK 770

ITTM 10
ITTM 20
ITTM 30
ITTM 40
ITTM 50
ITTM 60
ITTM 70
```

```
   1            THETAE(20,10))                                              |  |TM   80
        COMMON PLAMOM,PRTMOM,INOPLA                                        |  |TM   90
C----  THIS SUBROUTINE SOLVES FOR ELASTIC STRESS AND STRAIN DISTRIBUTIONS | |TM  100
        IF(ITCON.EQ.1)GO TO 10                                             |  |TM  110
        IF(INOPLA.EQ.0).AND.O(2).EQ.0..AND.O(3).EQ.0..AND.O(4).EQ.0.)      |  |TM  120
      1 GO TO 10                                                           |  |TM  130
        GO TO 60                                                           |  |TM  140
   10   DO 30 M=1,NTIME                                                    |  |TM  150
        DO 20 J=1,NAREA                                                    |  |TM  160
        STRESE(M,J) = XMOM(M)*(YBAR - Y(J))/XI                            |  |TM  170
   20   STRANE(M,J) = STRESE(M,J)/E(M,J)                                   |  |TM  180
   30   CONTINUE                                                           |  |TM  190
        DO 50 K=1,NTIME                                                    |  |TM  200
        YNA(K)=YBAR                                                        |  |TM  210
   50   THETAE(I,K) = (XMOM(K)*DX)/(E(K,1)*XI)                            |  |TM  220
        GO TO 220                                                          |  |TM  230
   60   DO 70 K=1,NTIME                                                    |  |TM  240
   70   THETAE(I,K)=(XMOM(K)*DX)/(E(K,NSECT)*XI)                          |  |TM  250
        DO 180 M=1,NTIME                                                   |  |TM  260
   80   YNA(M)=YBAR                                                        |  |TM  270
        F1 = 0.0                                                           |  |TM  280
   90   TOTF = 0.0                                                         |  |TM  290
        XM = 0.0                                                           |  |TM  300
        DO 120 J=1,NAREA                                                   |  |TM  310
        STRANE(M,J) = (YNA(M) - Y(J))*THETAE(I,M)/DX                      |  |TM  320
        STRESE(M,J) = STRANE(M,J)*E(M,J)                                   |  |TM  330
        FORCEE(J) = STRESE(M,J)*A(J)                                       |  |TM  340
        IF(I.EQ.3) GO TO 110                                               |  |TM  350
  110   CONTINUE                                                           |  |TM  360
  120   TOTF = TOTF + FORCEE(J)                                            |  |TM  370
        IF(TOTF.LT.0.0.AND.F1.GT.0.0) GO TO 140                           |  |TM  390
        IF(TOTF.GT.0.0.AND.F1.LT.0.0) GO TO 140                           |  |TM  400
        Y1 = YNA(M)                                                        |  |TM  410
        IF(TOTF.LT.0.0) YNA(M) = YNA(M) + DY                              |  |TM  420
        IF(TOTF.GT.0.0) YNA(M) = YNA(M) - DY                              |  |TM  430
        IF(TOTF.EQ.0.0) GO TO 150                                          |  |TM  440
        F1 = TOTF                                                          |  |TM  450
        GO TO 90                                                           |  |TM  460
  140   YNA(M) = YNA(M) - (ABS(TOTF)*(YNA(M) - Y1))/(ABS(TOTF) + ABS(F1)) |  |TM  470
  150   DO 160 K=1,NAREA                                                   |  |TM  490
        STRANE(M,K) = (YNA(M) - Y(K))*THETAE(I,M)/DX                      |  |TM  500
        STRESE(M,K) = STRANE(M,K)*E(M,K)                                   |  |TM  510
        FORCEE(K) = STRESE(M,K)*A(K)                                       |  |TM  520
  160   XM = XM + ABS(FORCEE(K)*(YNA(M) - Y(K)))                          |  |TM  530
        TOL = ABS( XM - XMOM(M))/XMOM(M)                                   |  |TM  540
        IF(ABS(TOL).LT..01) GO TO 170                                     |  |TM  550
        THETAE(I,M) = THETAE(I,M)*(XMOM(M)/XM)                            |  |TM  560
        GO TO 80                                                           |  |TM  570
  170   IF(NTCON.EQ.1) GO TO 190                                          |  |TM  580
  180   CONTINUE                                                           |  |TM  590
        GO TO 220                                                          |  |TM  600
  190   DO 210 M=2,NTIME                                                   |  |TM  610
        DO 200 N=1,NAREA                                                   |  |TM  620
        YNA(M) = YNA(1)                                                    |  |TM  630
        STRANE(M,N) = STRANE(1,N)*XMOM(M)/XMOM(1)                         |  |TM  640
        STRESE(M,N) = STRESE(1,N)*XMOM(M)/XMOM(1)                         |  |TM  650
  200   THETAE(I,M) = THETAE(I,1)*XMOM(M)/XMOM(1)                         |  |TM  660
  210   CONTINUE                                                           |  |TM  670
  220   RETURN
```

```
      END
      SUBROUTINE OUTPUT(INDGEU  ,  TS       ,  TR      ,  NRIB    ,  PITCH  ,      OUTP  10
     1RIBFLG  ,  DEPTH  ,  TC      ,  NCOR    ,  FLAT    ,  EDGE    ,  PHICOR ,      OUTP  20
     2TZEE    ,  NZEE    ,  ZPNED1  ,  ZPNED2  ,  ZEESF  ,  ZEESF1  ,  ZEEFF  ,      OUTP  30
     3ZEEFF1  ,  XLGTH   ,  INDBD   ,  BRAD    ,  BJED   ,  INDBUB  ,  INDSUP ,      OUTP  40
     4ALEN    ,  DXTIME  ,  PRESS   ,  TEMP    ,  XPRINT ,  NTIME   ,  NSTAT  ,      OUTP  50
     5DEFLE   ,  NUMCYC  ,  KCYCLE  ,  DEFL    ,  NAREA   ,  Y       ,  RESP   ,      OUTP  60
     6AM1,AM2,AM3,AM4,AM5,INDELA,PSTRAN,PLOAD,                                       OUTP  70
     7 XI    ,  YBAR    ,  Z       ,  PANWID  ,  DEFLIN  ,  INCYC  ,              OUTP  80
     8ITIME   ,  IEONTP  ,  IINTP   ,  IDIMEN  ,  ILOAD  ,  IEONST)                  OUTP  90
      DIMENSION  DXTIME (10)  ,  PRESS (10)  ,  TEMP (10)   ,  XPRINT (10)  ,OUTP 100
     1           KCYCLE (10)  ,  Y (60)    ,  Z(75)  ,  PLOAD(10)                    OUTP 110
      DIMENSION  DEFL (10,10)    ,  DEFLE (10,10)    ,  DEFLIN(10,10)                OUTP 120
      DIMENSION  RESP(10,60,10),  PSTRAN(10,60,10)                                   OUTP 130
     1    PLAMOM(10,10)    ,  PRTMOM(10,10)                                          OUTP 140
      COMMON  PLAMOM,PRTMOM,INDPLA                                                   OUTP 150
      NUMPRT=NSTAT                                                                   OUTP 160
      WRITE ( 6,2190 )                                                              OUTP 170
      WRITE(6,1300)AM1,AM2,AM3,AM4,AM5                                              OUTP 180
      GO TO (10  ,30  ,50  ,70  ), INDGEU                                           OUTP 190
   10 IF(IDIMEN.EQ.0)GO TO 20                                                       OUTP 200
      WRITE(6,2200) TS,TR,NRIB,PITCH,RIBFLG,DEPTH,                                  OUTP 210
     1XI,YBAR                                                                       OUTP 220
      GO TO 80                                                                      OUTP 230
   20 XI=XI*2.54*2.54*2.54*2.54                                                     OUTP 240
      YBAR=YBAR*2.54                                                                OUTP 250
      WRITE(6,1310) TS,TR,NRIB,PITCH,RIBFLG,DEPTH                                   OUTP 260
     1XI,YBAR                                                                       OUTP 270
      GO TO 80                                                                      OUTP 280
   30 IF(IDIMEN.EQ.0)GO TO 40                                                       OUTP 290
      WRITE (6,2210 ) TS,TC,NCOR,PITCH,FLAT,EDGE,PHICOR,DEPTH,                      OUTP 300
     1XI,YBAR                                                                       OUTP 310
      GO TO 80                                                                      OUTP 320
   40 XI=XI*2.54*2.54*2.54*2.54                                                     OUTP 330
      YBAR=YBAR*2.54                                                                OUTP 340
      WRITE(6,1320) TS,TC,NCOR,PITCH,FLAT,EDGE,PHICOR,DEPTH,                        OUTP 350
     1XI,YBAR                                                                       OUTP 360
      GO TO 80                                                                      OUTP 370
   50 IF(IDIMEN.EQ.0) GO TO 60                                                      OUTP 380
      WRITE ( 6,2220 ) TS,TZEE,NZEE,PITCH,ZPNED1,ZPNED2,DEPTH,ZEESF,               OUTP 390
     1                 ZEESF1,ZEEFF,ZEEFF1,                                         OUTP 400
     2XI,YBAR                                                                       OUTP 410
      GO TO 80                                                                      OUTP 420
   60 XI=XI*2.54*2.54*2.54*2.54                                                     OUTP 430
      YBAR=YBAR*2.54                                                                OUTP 440
      WRITE ( 6,1330 ) TS,TZEE,NZEE,PITCH,ZPNED1,ZPNED2,DEPTH,ZEESF,               OUTP 450
     1                 ZEESF1,ZEEFF,ZEEFF1,                                         OUTP 460
     2XI,YBAR                                                                       OUTP 470
      GO TO 80                                                                      OUTP 480
   70 CONTINUE                                                                      OUTP 490
   80 IF(IDIMEN.EQ.0) GO TO 90                                                      OUTP 500
      WRITE(6,2230) XLGTH,PANWID                                                    OUTP 510
      GO TO 100                                                                     OUTP 520
   90 WRITE(6,1340) XLGTH,PANWID                                                    OUTP 530
  100 CONTINUE                                                                      OUTP 540
      IF(INDBD.EQ.0) GO TO 150                                                      OUTP 550
      IF(BRAD.GT.0.0) GO TO 110                                                     OUTP 560
      WRITE ( 6,2240 )                                                              OUTP 570
      GO TO 120                                                                     OUTP 580
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110 WRITE ( 6,2250 )                                                    UUTP 590
120 IF(IDIMEN.EQ.0)GO TO 130                                            UUTP 600
    WRITE(6,2260) BRAD,BW(0)                                            UUTP 610
    GO TO 140                                                           UUTP 620
130 WRITE(6,1350) BRAD,BW(0)                                            UUTP 630
140 CONTINUE                                                            UUTP 640
150 WRITE ( 6,2270 )                                                    UUTP 650
    IF(INDPLA.EQ.0)GO TO 220                                            UUTP 660
    WRITE(6,1360)                                                       UUTP 670
    WRITE(6,2190)                                                       UUTP 680
    WRITE(6,1370)                                                       UUTP 690
    IF(IDIMEN.EQ.0)GO TO 170                                            UUTP 700
    WRITE(6,1380)                                                       UUTP 710
    WRITE(6,1390) (XPRINT(N),N=1,NSTAT)                                 UUTP 720
    WRITE(6,1400)                                                       UUTP 730
    DO 160  M=1,NTIME                                                   UUTP 740
    WRITE(6,1410))XTIME(M),(PRTMOM(I,M),I=1,NSTAT)                      UUTP 750
160 CONTINUE                                                            UUTP 760
    GO TO 210                                                           UUTP 770
170 CONTINUE                                                            UUTP 780
    DO 180  N=1,NSTAT                                                   UUTP 790
180 XPRINT(N)=XPRINT(N)*2.54                                            UUTP 800
    WRITE(6,1420)                                                       UUTP 810
    WRITE(6,1390) (XPRINT(N),N=1,NSTAT)                                 UUTP 820
    WRITE(6,1430)                                                       UUTP 830
    DO 200  M=1,NTIME                                                   UUTP 840
    DO 190  I=1,NSTAT                                                   UUTP 850
190 PRTMOM(I,M)=PRTMOM(I,M)*.4536*2.54                                  UUTP 860
200 WRITE(6,1410))XTIME(M),(PRTMOM(I,M),I=1,NSTAT)                      UUTP 870
210 CONTINUE                                                            UUTP 880
    GO TO 350                                                           UUTP 890
220 CONTINUE                                                            UUTP 900
    IF(INDLOD.EQ.1) GO TO 240                                           UUTP 910
    WRITE ( 6,2280 )                                                    UUTP 920
    IF(INDSUP.EQ.1) GO TO 230                                           UUTP 930
    WRITE ( 6,2290 )                                                    UUTP 940
    GO TO 350                                                           UUTP 950
230 WRITE ( 6,2300 )                                                    UUTP 960
    GO TO 350                                                           UUTP 970
240 IF(IDIMEN.EQ.0)GO TO 250                                            UUTP 980
    WRITE(6,1440)ALEN                                                   UUTP 990
    GO TO 260                                                           UUTP1000
250 WRITE(6,1450)ALEN                                                   UUTP1010
260 CONTINUE                                                            UUTP1020
    WRITE(6,1460)                                                       UUTP1030
    IF(ITIME.EQ.0) GO TO 270                                            UUTP1040
    WRITE(6,1470)                                                       UUTP1050
    GO TO 280                                                           UUTP1060
270 WRITE(6,1480)                                                       UUTP1070
280 CONTINUE                                                            UUTP1080
    IF(ILOAD.EQ.0.)GO TO 290                                            UUTP1090
    WRITE(6,1490)                                                       UUTP1100
    GO TO 310                                                           UUTP1110
290 WRITE(6,1500)                                                       UUTP1120
    DO 300  LL=1,NTIME                                                  UUTP1130
300 PLOAD(LL)=PLOAD(LL)*.45359                                          UUTP1140
310 CONTINUE                                                            UUTP1150
    IF(IINTP.EQ.0)GO TO 320                                             UUTP1160
    WRITE(6,1510)                                                       UUTP1170
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      GO TO 330)                                                          UU IP1180
 320  WRITE(6,1520)                                                       UU IP1190
 330  CONTINUE                                                            UU IP1200
      WRITE(6,1530)                                                       UU IP1210
      WRITE(6,1540)DXTIME(1),PLOAD(1),TEMP(1)                             UU IP1220
      IF(NTIME.EQ.1) GO TO 340                                           UU IP1230
      WRITE(6,2330)(DXTIME(N-1),DXTIME(N),PLOAD(N),TEMP(N),N=2,NTIME)    UU IP1240
 340  CONTINUE                                                            UU IP1250
      GO TO 430                                                           UU IP1260
 350  CONTINUE                                                            UU IP1270
      WRITE(6,1460)                                                       UU IP1280
      IF(ITIME.EQ.0) GO TO 360                                           UU IP1290
      WRITE(6,1470)                                                       UU IP1300
      GO TO 370                                                           UU IP1310
 360  WRITE(6,1480)                                                       UU IP1320
 370  CONTINUE                                                            UU IP1330
      IF(ILOAD.EQ.0) GO TO 380                                           UU IP1340
      WRITE(6,1550)                                                       UU IP1350
      GO TO 400                                                           UU IP1360
 380  WRITE(6,1560)                                                       UU IP1370
      DO 390  LL=1,NTIME                                                  UU IP1380
 390  PRESS(LL)=PRESS(LL)*6894.8                                          UU IP1390
 400  CONTINUE                                                            UU IP1400
      IF(IINTP.EQ.0) GO TO 410                                           UU IP1410
      WRITE(6,1510)                                                       UU IP1420
      GO TO 420                                                           UU IP1430
 410  WRITE(6,1520)                                                       UU IP1440
 420  CONTINUE                                                            UU IP1450
      WRITE(6,1570)                                                       UU IP1460
      WRITE(6,1540)DXTIME(1),PRESS(1),TEMP(1)                             UU IP1470
      IF(NTIME.EQ.1)GO TO 430                                            UU IP1480
      WRITE(6,2330)(DXTIME(N-1),DXTIME(N),PRESS(N),TEMP(N),N=2,NTIME)    UU IP1490
 430  CONTINUE                                                            UU IP1500
      WRITE(6,2190)                                                       UU IP1510
      WRITE(6,1580)                                                       UU IP1520
      WRITE(6,1590)Z(1)                                                   UU IP1530
      IF(Z(2).EQ.0.)GO TO 440                                            UU IP1540
      WRITE(6,1600)Z(2)                                                   UU IP1550
 440  CONTINUE                                                            UU IP1560
      IF(Z(3).EQ.0.)GO TO 450                                            UU IP1570
      WRITE(6,1610)Z(3)                                                   UU IP1580
 450  CONTINUE                                                            UU IP1590
      IF(Z(4).EQ.0.)GO TO 460                                            UU IP1600
      WRITE(6,1620)Z(4)                                                   UU IP1610
 460  CONTINUE                                                            UU IP1620
      IF(Z(5).EQ.0.)GO TO 470                                            UU IP1630
      WRITE(6,1630)Z(5)                                                   UU IP1640
 470  CONTINUE                                                            UU IP1650
      IF(Z(6).EQ.0.)GO TO 480                                            UU IP1660
      WRITE(6,1640)Z(6)                                                   UU IP1670
 480  CONTINUE                                                            UU IP1680
      IF(Z(7).EQ.0.)GO TO 490                                            UU IP1690
      WRITE(6,1650)Z(7)                                                   UU IP1700
 490  CONTINUE                                                            UU IP1710
      IF(Z(8).EQ.0.)GO TO 500                                            UU IP1720
      WRITE(6,1660)Z(8)                                                   UU IP1730
 500  CONTINUE                                                            UU IP1740
      IF(Z(9).EQ.0.)GO TO 510                                            UU IP1750
      WRITE(6,1670)Z(9)                                                   UU IP1760
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510 CONTINUE                                                    UUIP1770
    IF(Z(10).EQ.0.)GO TO 520                                    UUIP1780
    WRITE(6,1680)Z(10)                                          UUIP1790
520 CONTINUE                                                    UUIP1800
    IF(Z(11).EQ.0.)GO TO 530                                    UUIP1810
    WRITE(6,1690)Z(11)                                          UUIP1820
530 CONTINUE                                                    UUIP1830
    IF(Z(12).EQ.0.)GO TO 540                                    UUIP1840
    WRITE(6,1700)Z(12)                                          UUIP1850
540 CONTINUE                                                    UUIP1860
    IF(Z(13).EQ.0.)GO TO 550                                    UUIP1870
    WRITE(6,1710)Z(13)                                          UUIP1880
550 CONTINUE                                                    UUIP1890
    IF(Z(14).EQ.0.)GO TO 560                                    UUIP1900
    WRITE(6,1720)Z(14)                                          UUIP1910
560 CONTINUE                                                    UUIP1920
    IF(Z(15).EQ.0.)GO TO 570                                    UUIP1930
    WRITE(6,1730)Z(15)                                          UUIP1940
570 CONTINUE                                                    UUIP1950
    IF(Z(16).EQ.0.)GO TO 580                                    UUIP1960
    WRITE(6,1740)Z(16)                                          UUIP1970
580 CONTINUE                                                    UUIP1980
    IF(Z(17).EQ.0.)GO TO 590                                    UUIP1990
    WRITE(6,1750)Z(17)                                          UUIP2000
590 CONTINUE                                                    UUIP2010
    IF(Z(18).EQ.0.)GO TO 600                                    UUIP2020
    WRITE(6,1760)Z(18)                                          UUIP2030
600 CONTINUE                                                    UUIP2040
    IF(Z(19).EQ.0.)GO TO 610                                    UUIP2050
    WRITE(6,1770)Z(19)                                          UUIP2060
610 CONTINUE                                                    UUIP2070
    IF(Z(20).EQ.0.)GO TO 620                                    UUIP2080
    WRITE(6,1780)Z(20)                                          UUIP2090
620 CONTINUE                                                    UUIP2100
    IF(Z(21).EQ.0.)GO TO 630                                    UUIP2110
    WRITE(6,1790)Z(21)                                          UUIP2120
630 CONTINUE                                                    UUIP2130
    IF(Z(22).EQ.0.)GO TO 640                                    UUIP2140
    WRITE(6,1800)Z(22)                                          UUIP2150
640 CONTINUE                                                    UUIP2160
    IF(Z(23).EQ.0.)GO TO 650                                    UUIP2170
    WRITE(6,1810)Z(23)                                          UUIP2180
650 CONTINUE                                                    UUIP2190
    IF(Z(24).EQ.0.)GO TO 660                                    UUIP2200
    WRITE(6,1820)Z(24)                                          UUIP2210
660 CONTINUE                                                    UUIP2220
    IF(Z(25).EQ.0.)GO TO 670                                    UUIP2230
    WRITE(6,1830)Z(25)                                          UUIP2240
670 CONTINUE                                                    UUIP2250
    IF(Z(26).EQ.0.)GO TO 680                                    UUIP2260
    WRITE(6,1840)Z(26)                                          UUIP2270
680 CONTINUE                                                    UUIP2280
    IF(Z(27).EQ.0.)GO TO 690                                    UUIP2290
    WRITE(6,1850)Z(27)                                          UUIP2300
690 CONTINUE                                                    UUIP2310
    IF(Z(28).EQ.0.)GO TO 700                                    UUIP2320
    WRITE(6,1860)Z(28)                                          UUIP2330
700 CONTINUE                                                    UUIP2340
    IF(Z(29).EQ.0.)GO TO 710                                    UUIP2350
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      WRITE(6,1870)Z(29)                                       UU IP2360
 710  CONTINUE                                                 UU IP2370
      IF(Z(31).EQ.0.)GO TO 720                                 UU IP2380
      WRITE(6,1880)Z(30)                                       UU IP2390
 720  CONTINUE                                                 UU IP2400
      IF(Z(31).EQ.0.)GO TO 730                                 UU IP2410
      WRITE(6,1890)Z(31)                                       UU IP2420
 730  CONTINUE                                                 UU IP2430
      IF(Z(32).EQ.0.)GO TO 740                                 UU IP2440
      WRITE(6,1900)Z(32)                                       UU IP2450
 740  CONTINUE                                                 UU IP2460
      IF(Z(33).EQ.0.)GO TO 750                                 UU IP2470
      WRITE(6,1910)Z(33)                                       UU IP2480
 750  CONTINUE                                                 UU IP2490
      IF(Z(34).EQ.0.)GO TO 760                                 UU IP2500
      WRITE(6,1920)Z(34)                                       UU IP2510
 760  CONTINUE                                                 UU IP2520
      IF(Z(35).EQ.0.)GO TO 770                                 UU IP2530
      WRITE(6,1930)Z(35)                                       UU IP2540
 770  CONTINUE                                                 UU IP2550
      IF(Z(36).EQ.0.)GO TO 780                                 UU IP2560
      WRITE(6,1940)Z(36)                                       UU IP2570
 780  CONTINUE                                                 UU IP2580
      IF(Z(37).EQ.0.)GO TO 790                                 UU IP2590
      WRITE(6,1950)Z(37)                                       UU IP2600
 790  CONTINUE                                                 UU IP2610
      IF(Z(38).EQ.0.)GO TO 800                                 UU IP2620
      WRITE(6,1960)Z(38)                                       UU IP2630
 800  CONTINUE                                                 UU IP2640
      IF(Z(39).EQ.0.)GO TO 810                                 UU IP2650
      WRITE(6,1970)Z(39)                                       UU IP2660
 810  CONTINUE                                                 UU IP2670
      IF(Z(40).EQ.0.)GO TO 820                                 UU IP2680
      WRITE(6,1980)Z(40)                                       UU IP2690
 820  CONTINUE                                                 UU IP2700
      IF(Z(41).EQ.0.)GO TO 830                                 UU IP2710
      WRITE(6,1990)Z(41)                                       UU IP2720
 830  CONTINUE                                                 UU IP2730
      IF(Z(42).EQ.0.)GO TO 840                                 UU IP2740
      WRITE(6,2000)Z(42)                                       UU IP2750
 840  CONTINUE                                                 UU IP2760
      IF(Z(43).EQ.0.)GO TO 850                                 UU IP2770
      WRITE(6,2010)Z(43)                                       UU IP2780
 850  CONTINUE                                                 UU IP2790
      IF(Z(44).EQ.0.)GO TO 860                                 UU IP2800
      WRITE(6,2020)Z(44)                                       UU IP2810
 860  CONTINUE                                                 UU IP2820
      IF(Z(45).EQ.0.) GO TO 870                                UU IP2830
      WRITE(6,2030)Z(45)                                       UU IP2840
 870  CONTINUE                                                 UU IP2850
      IF(IFTHF.EQ.0)GO TO 880                                  UU IP2860
      WRITE(6,2040)                                            UU IP2870
      GO TO 890                                                UU IP2880
 880  WRITE(6,2050)                                            UU IP2890
 890  CONTINUE                                                 UU IP2900
      IF(IFONTP.EQ.0)GO TO 900                                 UU IP2910
      WRITE(6,2060)                                            UU IP2920
      GO TO 910                                                UU IP2930
 900  WRITE(6,2070)                                            UU IP2940
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 910  CONTINUE
      IF(IFONST.EQ.0)GO TO 920
      WRITE(6,2080)
      GO TO 930
 920  WRITE(6,2090)
 930  CONTINUE
      IF(IDIMEN.EQ.0)GO TO 970
      WRITE(6,2340)
      IF(ITIME.EQ.0)GO TO 940
      WRITE(6,2350) (XPRINT(N),N=1,NSTAT )
      GO TO 950
 940  WRITE(6,2100) (XPRINT(N),N=1,NSTAT )
 950  CONTINUE
      DO 960  M=1,NTIME
      WRITE ( 6,2360 ) DXTIME(M),(DEFLE(M,N),N=1,NSTAT )
 960  CONTINUE
      GO TO 1030
 970  CONTINUE
      WRITE(6,2110)
      IF(ITIME.EQ.0)GO TO 980
      WRITE(6,2350) (XPRINT(N),N=1,NSTAT )
      GO TO 990
 980  WRITE(6,2100) (XPRINT(N),N=1,NSTAT )
 990  CONTINUE
      DO 1010 M=1,NTIME
      DO 1000 N=1,NSTAT
      DEFLE(M,N)=DEFLE(M,N)*2.54
1000  CONTINUE
1010  CONTINUE
      DO 1020 M=1,NTIME
      WRITE(6,2360)DXTIME(M),(DEFLE(M,N),N=1,NSTAT)
1020  CONTINUE
1030  CONTINUE
      IF(INDELA.EQ.1) RETURN
      IF(INCYC.EQ.0) GO TO 1100
      IF(IDIMEN.EQ.0)GO TO 1050
      WRITE(6,2120)
      WRITE(6,2130)  (XPRINT(N),N=1,NSTAT)
      DO 1040 M=1,NTIME
      WRITE(6,2140) DXTIME(M),(DEFLIN(M,N),N=1,NSTAT)
1040  CONTINUE
      GO TO 1090
1050  WRITE(6,2150)
      WRITE(6,2130) (XPRINT(N),N=1,NSTAT)
      DO 1070 M=1,NTIME
      DO 1060 N=1,NSTAT
      DEFLIN(M,N)=DEFLIN(M,N)*2.54
1060  CONTINUE
1070  CONTINUE
      DO 1080 M=1,NTIME
      WRITE(6,2140)DXTIME(M),(DEFLIN(M,N),N=1,NSTAT)
1080  CONTINUE
1090  CONTINUE
1100  CONTINUE
      IF(IDIMEN.EQ.0.)GO TO 1120
      WRITE ( 6,2370 )
      WRITE ( 6,2380 ) (XPRINT(N),N=1,NSTAT )
      DO 1110 M=1,NUMCYC
      WRITE ( 6,2390 ) KCYCLE(M),(DEFL(M,N),N=1,NSTAT )
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UUTP2950
UUTP2960
UUTP2970
UUTP2980
UUTP2990
UUTP3000
UUTP3010
UUTP3020
UUTP3030
UUTP3040
UUTP3050
UUTP3060
UUTP3070
UUTP3080
UUTP3090
UUTP3100
UUTP3110
UUTP3120
UUTP3130
UUTP3140
UUTP3150
UUTP3160
UUTP3170
UUTP3180
UUTP3190
UUTP3200
UUTP3210
UUTP3220
UUTP3230
UUTP3240
UUTP3250
UUTP3260
UUTP3270
UUTP3280
UUTP3290
UUTP3300
UUTP3310
UUTP3320
UUTP3330
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UUTP3430
UUTP3440
UUTP3450
UUTP3460
UUTP3470
UUTP3480
UUTP3490
UUTP3500
UUTP3510
UUTP3520
UUTP3530
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1110 CONTINUE                                                        UUIP3540
     GO TO 1160                                                      UUIP3550
1120 WRITE(6,2160)                                                   UUIP3560
     WRITE(6,2380) (XPRINT(N),N=1,NSTAT)                             UUIP3570
     DO 1140 N=1,NUMCYC                                              UUIP3580
     DO 1130 N=1,NSTAT                                               UUIP3590
     DEFL(M,N)=DEFL(M,N)*2.54                                        UUIP3600
1130 CONTINUE                                                        UUIP3610
1140 CONTINUE                                                        UUIP3620
     DO 1150 N=1,NUMCYC                                              UUIP3630
     WRITE(6,2390 ) KCYCLE(M),(DEFL(M,N),N=1,NSTAT)                  UUIP3640
1150 CONTINUE                                                        UUIP3650
1160 CONTINUE                                                        UUIP3660
     IF(IDIMEN.EQ.1)GO TO 1180                                       UUIP3670
     DO 1170 N=1,NAREA                                               UUIP3680
1170 Y(N)=Y(N)*2.54                                                  UUIP3690
1180 CONTINUE                                                        UUIP3700
     DO 1290 N1=1,NUMCYC                                             UUIP3710
     IF(IDIMEN.EQ.0) GO TO 1190                                      UUIP3720
     GO TO 1200                                                      UUIP3730
1190 WRITE(6,2170)KCYCLE(NL)                                         UUIP3740
     GO TO 1210                                                      UUIP3750
1200 WRITE(6,2430)KCYCLE(NL)                                         UUIP3760
1210 CONTINUE                                                        UUIP3770
     WRITE (6,2440) (XPRINT(N),N=1,NSTAT )                           UUIP3780
     DO 1220 N2=1,NAREA                                              UUIP3790
     WRITE (6,2450) Y(N2), (PSTRAN(N3,N2,NL),N3=1,NSTAT )            UUIP3800
1220 CONTINUE                                                        UUIP3810
     IF(IDIMEN.EQ.0)GO TO 1230                                       UUIP3820
     GO TO 1260                                                      UUIP3830
1230 WRITE(6,2180)KCYCLE(NL)                                         UUIP3840
     DO 1250 L2=1,NAREA                                              UUIP3850
     DO 1240 L3=1,NSTAT                                              UUIP3860
     RESP(L3,L2,N1)=RESP(L3,L2,N1)*.0068948                          UUIP3870
1240 CONTINUE                                                        UUIP3880
1250 CONTINUE                                                        UUIP3890
     GO TO 1270                                                      UUIP3900
1260 WRITE(6,2400)KCYCLE(NL)                                         UUIP3910
1270 CONTINUE                                                        UUIP3920
     WRITE ( 6,2410 ) (XPRINT(N),N=1,NSTAT )                         UUIP3930
     DO 1280 N2=1,NAREA                                              UUIP3940
     WRITE (6,2420) Y(N2) , (RESP(N3,N2,N1),N3=1,NSTAT)              UUIP3950
1280 CONTINUE                                                        UUIP3960
1290 CONTINUE                                                        UUIP3970
     RETURN                                                          UUIP3980
1300 FORMAT(50X,5A10,//)                                            UUIP3990
1310 FORMAT(43X,23HRIB STIFFENED TPS PANEL//53X,12HSKIN GAGE = ,F5.4,UUIP4000
    17H CM    /53X,11HRIB GAGE = ,F5.4,7H CM   /53X,17HNUMBER OF RIBS UUIP4010
    2= ,I3/53X,15HPITCH LENGTH = ,F6.3,7H CM   /53X,20HPANEL EDGE LENGUUIP4020
    3TH = ,F6.3,7H CM   /53X,14HPANEL DEPTH = ,F5.3,7H CM    /,       UUIP4030
    453X,31HCALCULATED MOMENT OF INERTIA = ,F10.7,5H CM**4/           UUIP4040
    553X,23HELASTIC NEUTRAL AXIS = ,F5.3,7H CM    /)                  UUIP4050
1320 FORMAT(43X,28HSINGLE FACED CORRUGATION TPS//53X,12HSKIN GAGE = , UUIP4060
    1F5.4,7H CM    /53X,19HCORRUGATION GAGE = ,F5.4,7H CM   /53X,      UUIP4070
    225HNUMBER OF CORRUGATIONS = ,I3/53X,15HPITCH LENGTH = ,F6.3,     UUIP4080
    37H CM    /53X,14HFLAT LENGTH = ,F6.3,7H CM   /53X,               UUIP4090
    420HPANEL EDGE LENGTH = ,F6.3,7H CM    /53X,20HCORRUGATION ANGLE = UUIP4100
    5,F6.3,8H DEGREES/53X,14HPANEL DEPTH = ,F5.3,7H CM    /,          UUIP4110
    653X,31HCALCULATED MOMENT OF INERTIA = ,F10.7,6H CM**4/           UUIP4120
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      753X,23HELASTIC NEUTRAL AXIS = ,F5.3,7H CM      /)                    UUIP4130
1330 FORMAT(43X,21HZ STIFFENED TPS PANEL//53X,12HSKIN GAGE = ,F5.4,       UUIP4140
    17H CM    /53X,9HZ GAGE = ,F5.4,7H CM    /53X,25HNUMBER OF Z STIFFEUUIP4150
    2NERS = ,I3/53X,15HPITCH LENGTH = ,F6.3,7H CM    /53X,             UUIP4160
    321HPANEL EDGE LENGTHS = ,F5.3,5H AND ,F6.3,7H CM    /53X,         UUIP4170
    414HPANEL DEPTH = ,F5.3,7H CM    /53X,27HZ FLANGE LENGTHS AT SKIN =UUIP4180
    5 ,F5.3,5H AND ,F5.3,7H CM    /53X,24HZ FREE FLANGE LENGTHS = ,    UUIP4190
    6F5.3,5H AND ,F5.3,7H CM    /,                                     UUIP4200
    753X,31HCALCULATED MOMENT OF INERTIA = ,F10.7,6H CM**4/            UUIP4210
    853X,23HELASTIC NEUTRAL AXIS = ,F5.3,7H CM    /)                   UUIP4220
1340 FORMAT(43X,15HPANEL LENGTH = ,F6.2,7H CM    /                      UUIP4230
    1,43X,14HPANEL WIDTH = ,F6.2,7H CM    //)                          UUIP4240
1350 FORMAT(53X,9HRADIUS = ,F6.3,7H CM    /53X,9HWIDTH = ,F5.3,         UUIP4250
    17H CM    /)                                                       UUIP4260
1360 FORMAT(53X,31HUNIFORM PRESSURE (PLATE OPTION))                     UUIP4270
1370 FORMAT(52X,27HBENDING MOMENT DISTRIBUTION)                         UUIP4280
1380 FORMAT(///25X,21HBEAM STATION (INCHES))                            UUIP4290
1390 FORMAT(/11X,4HTIME,9X,10(F5.2,5X)/)                                UUIP4300
1400 FORMAT(62X, 7H(IN LBS))                                            UUIP4310
1410 FORMAT(10X,F6.2,4X,10(F10.2))                                      UUIP4320
1420 FORMAT(///25X,17HBEAM STATION (CM))                                UUIP4330
1430 FORMAT(60X,10H(CM KILOS))                                          UUIP4340
1440 FORMAT(53X,50H TWO POINT LOADS , DISTANCE FROM SUPPORT TO LOAD =,  UUIP4350
    1F5.2,7H INCHES//)                                                 UUIP4360
1450 FORMAT(53X,50H TWO POINT LOADS , DISTANCE FROM SUPPORT TO LOAD =,  UUIP4370
    1F5.2,3H CM//)                                                     UUIP4380
1460 FORMAT(42X,/////,16H TRAJECTORY DATA/)                             UUIP4390
1470 FORMAT(45X,15H TIME (SECONDS))                                     UUIP4400
1480 FORMAT(45X,15H TIME (MINUTES))                                     UUIP4410
1490 FORMAT(45X,11H LOAD (LBS))                                         UUIP4420
1500 FORMAT(45X,13H LOAD (KILOS))                                       UUIP4430
1510 FORMAT(45X,20H TEMPERATURE (DEG F)//)                              UUIP4440
1520 FORMAT(45X,20H TEMPERATURE (DEG K)//)                              UUIP4450
1530 FORMAT(55X,4HTIME,16X,10H    LOAD    ,6X,12HMIDSPAN SKIN/           UUIP4460
    151X,5HSTART,4X,3HEND,28X,11HTEMPERATURE//)                        UUIP4470
1540 FORMAT(52X,4H0.00,3X,F6.2,11X,F8.3,13X,F6.1)                       UUIP4480
1550 FORMAT(46X,14HPRESSURE (PSI))                                      UUIP4490
1560 FORMAT(46X,13HPRESSURE (PA))                                       UUIP4500
1570 FORMAT(55X,4HTIME,16X,10H PRESSURE ,6X,12HMIDSPAN SKIN/             UUIP4510
    151X,5HSTART,4X,3HEND,28X,11HTEMPERATURE//)                        UUIP4520
1580 FORMAT(/////,49X,32HCYCLIC CREEP EQUATION DEFINITION ///)          UUIP4530
1590 FORMAT(40X,12HLN(STRAIN)= ,F12.5)                                  UUIP4540
1600 FORMAT(52X,F12.5,10H *(STRESS))                                    UUIP4550
1610 FORMAT(52X,F12.5, 8H *(TEMP))                                      UUIP4560
1620 FORMAT(52X,F12.5, 8H *(TIME))                                      UUIP4570
1630 FORMAT(52X,F12.5,11H *(1./TEMP))                                   UUIP4580
1640 FORMAT(52X,F12.5,11H *LN(TIME) )                                   UUIP4590
1650 FORMAT(52X,F12.5,13H *LN(STRESS) )                                 UUIP4600
1660 FORMAT(52X,F12.5,11H *LN(TEMP) )                                   UUIP4610
1670 FORMAT(52X,F12.5,13H *(STRESS)**2)                                 UUIP4620
1680 FORMAT(52X,F12.5,13H *(STRESS)**3)                                 UUIP4630
1690 FORMAT(52X,F12.5,14H *(1./TEMP)**2)                                UUIP4640
1700 FORMAT(52X,F12.5,14H *(1./TEMP)**3)                                UUIP4650
1710 FORMAT(52X,F12.5,16H *(STRESS)(TEMP))                              UUIP4660
1720 FORMAT(52X,F12.5,17H *(STRESS)/(TEMP))                             UUIP4670
1730 FORMAT(52X,F12.5,18H *(STRESS*TEMP)**2)                            UUIP4680
1740 FORMAT(52X,F12.5,18H *(STRESS*TEMP)**3)                            UUIP4690
1750 FORMAT(52X,F12.5,18H *(STRESS/TEMP)**2)                            UUIP4700
1760 FORMAT(52X,F12.5,18H *(STRESS/TEMP)**3)                            UUIP4710
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1770 FORMAT(52X,E12.5,17H *(LN(STRESS))**2)                          UUIP4720
1780 FORMAT(52X,E12.5,17H *(LN(STRESS))**3)                          UUIP4730
1790 FORMAT(52X,E12.5,17H *STRESS*LN(TEMP))                          UUIP4740
1800 FORMAT(52X,E12.5,17H *TEMP*LN(STRESS))                          UUIP4750
1810 FORMAT(52X,E12.5,21H *(LN(STRESS)*LN(TEMP))                     UUIP4760
1820 FORMAT(52X,E12.5,18H *TIME*STRESS*TEMP)                         UUIP4770
1830 FORMAT(52X,E12.5,23H *(TIME*STRESS*TEMP)**2)                    UUIP4780
1840 FORMAT(52X,E12.5,23H *(TIME*STRESS*TEMP)**3)                    UUIP4790
1850 FORMAT(52X,E12.5,11H *(TIME)**2)                                UUIP4800
1860 FORMAT(52X,E12.5,11H *(TIME)**3)                                UUIP4810
1870 FORMAT(52X,E12.5,15H *(LN(TIME))**2)                            UUIP4820
1880 FORMAT(52X,E12.5,15H *(LN(TIME))**3)                            UUIP4830
1890 FORMAT(52X,E12.5,11H *(TEMP)**2)                                UUIP4840
1900 FORMAT(52X,E12.5,11H *(TEMP)**3)                                UUIP4850
1910 FORMAT(52X,E12.5,15H *(LN(TEMP))**2)                            UUIP4860
1920 FORMAT(52X,E12.5,15H *(LN(TEMP))**3)                            UUIP4870
1930 FORMAT(52X,E12.5,17H *STRESS*LN(TIME))                          UUIP4880
1940 FORMAT(52X,E12.5,15H *TEMP*LN(TIME))                            UUIP4890
1950 FORMAT(52X,E12.5,17H *TIME*LN(STRESS))                          UUIP4900
1960 FORMAT(52X,E12.5,15H *TIME*LN(TEMP))                            UUIP4910
1970 FORMAT(52X,E12.5,21H *LN(STRESS)*LN(TIME))                      UUIP4920
1980 FORMAT(52X,E12.5,19H *LN(TIME)*LN(TEMP))                        UUIP4930
1990 FORMAT(52X,E12.5,19H *(LN(STRESS))/TEMP)                        UUIP4940
2000 FORMAT(52X,E12.5,17H *(LN(TIME))/TEMP)                          UUIP4950
2010 FORMAT(52X,E12.5,30H *(LN(TIME))*(LN(STRESS))/TEMP)             UUIP4960
2020 FORMAT(52X,E12.5,13H *TIME*STRESS)                             UUIP4970
2030 FORMAT(52X,E12.5,11H *TIME*TEMP)                                UUIP4980
2040 FORMAT(//,50X,24HWHERE     TIME = MINUTES)                      UUIP4990
2050 FORMAT(//,50X,24HWHERE     TIME = HOURS )                       UUIP5000
2060 FORMAT(60X,25HTEMPERATURE = DEG F/1000.)                        UUIP5010
2070 FORMAT(60X,25HTEMPERATURE = DEG K/1000.)                        UUIP5020
2080 FORMAT(60X,12HSTRESS = KSI)                                     UUIP5030
2090 FORMAT(60X,12HSTRESS = MPA)                                     UUIP5040
2100 FORMAT(13X,9HTIME(HR) ,3X,10(F5.2,5X)/)                         UUIP5050
2110 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//51X,       UUIP5060
     126HELASTIC DEFLECTION SUMMARY////23X,21HBEAM STATION (CM)    ) UUIP5070
2120 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//47X,       UUIP5080
     136HFIRST CYCLE CREEP DEFLECTION SUMMARY////23X,                UUIP5090
     221HBEAM STATION (INCHES))                                      UUIP5100
2130 FORMAT(13X,4HTIME,9X,10(F5.2,6X)/)                              UUIP5110
2140 FORMAT(11X,F7.2,6X,10(F10.5,1X))                                UUIP5120
2150 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//47X,       UUIP5130
     136HFIRST CYCLE CREEP DEFLECTION SUMMARY////23X,                UUIP5140
     221HBEAM STATION (CM)    )                                      UUIP5150
2160 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//53X,       UUIP5160
     124HCREEP DEFLECTION SUMMARY////23X,21HBEAM STATION (CM)    )   UUIP5170
2170 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//51X,       UUIP5180
     123HCREEP STRAINS (PERCENT)//64X,6HCYCLE ,I3////25X,            UUIP5190
     221HBEAM STATION (CM)    )                                      UUIP5200
2180 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//57X,       UUIP5210
     123HRESIDUAL STRESSES (MPA)//64X,6HCYCLE ,I3////25X,            UUIP5220
     221HBEAM STATION (CM)    )                                      UUIP5230
2190 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM/)           UUIP5240
2200 FORMAT(43X,23HRIB STIFFENED TPS PANEL//53X,12HSKIN GAGE = ,F5.4,UUIP5250
     17H INCHES/53X,11HRIB GAGE = ,F5.4,7H INCHES/53X,17HNUMBER OF RIBSUUIP5260
     2= ,I3/53X,15HPITCH LENGTH = ,F6.3,7H INCHES/53X,20HPANEL EDGE LENGUUIP5270
     3TH = ,F6.3,7H INCHES/53X,14HPANEL DEPTH = ,F5.3,7H INCHES/,     UUIP5280
     453X,31HCALCULATED MOMENT OF INERTIA = ,F10.7,6H IN**4/          UUIP5290
     553X,23HELASTIC NEUTRAL AXIS = ,F5.3,7H INCHES/)                 UUIP5300
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2210 FORMAT(43X,28HSINGLE -FACED CORRUGATION TPS//53X,12HSKIN GAGE = ,   OUTP5310
     1F5.4,7H INCHES/53X,19HCORRUGATION GAGE = ,F5.4,7H INCHES/53X,        OUTP5320
     225HNUMBER OF CORRUGATIONS = ,I3/53X,15HPITCH LENGTH = ,F6.3,         OUTP5330
     37H INCHES/53X,14HFLAT LENGTH = ,F6.3,7H INCHES/53X,                  OUTP5340
     420HPANEL EDGE LENGTH = ,F5.3,7H INCHES/53X,20HCORRUGATION ANGLE = OUTP5350
     5,F6.3,8H DEGREES/53X,14HPANEL DEPTH = ,F5.3,7H INCHES/,              OUTP5360
     653X,31HCALCULATED MOMENT OF INERTIA = ,F10.7,6H IN**4/               OUTP5370
     753X,23HELASTIC NEUTRAL AXIS = ,F5.3,7H INCHES/)                      OUTP5380
2220 FORMAT(43X,21HZ STIFFENED TPS PANEL//53X,12HSKIN GAGE = ,F5.4,        OUTP5390
     17H INCHES/53X,9HZ GAGE = ,F5.4,7H INCHES/53X,25HNUMBER OF Z STIFFE OUTP5400
     2NERS = ,I3/53X,15HPITCH LENGTH = ,F5.3,7H INCHES/53X,                OUTP5410
     321HPANEL EDGE LENGTHS = ,F6.3,5H AND ,F6.3,7H INCHES/53X,            OUTP5420
     414HPANEL DEPTH = ,F5.3,7H INCHES/53X,27HZ FLANGE LENGTHS AT SKIN =OUTP5430
     5 ,F5.3,5H AND ,F5.3,7H INCHES/53X,24HZ FREE FLANGE LENGTHS = ,       OUTP5440
     6F5.3,5H AND ,F5.3,7H INCHES/                                         OUTP5450
     753X,31HCALCULATED MOMENT OF INERTIA = ,F10.7,6H IN**4/               OUTP5460
     853X,23HELASTIC NEUTRAL AXIS = ,F5.3,7H INCHES/)                      OUTP5470
2230 FORMAT(43X,15HPANEL LENGTH = ,F6.2,7H INCHES/                         OUTP5480
     1,43X,14HPANEL WIDTH = ,F5.2,7H INCHES//)                             OUTP5490
2240 FORMAT(43X,13HNEGATIVE BEAD)                                          OUTP5500
2250 FORMAT(43X,13HPOSITIVE BEAD)                                          OUTP5510
2260 FORMAT(53X,9HRADIUS = ,F6.3,7H INCHES/53X,9HWIDTH = ,F6.3,            OUTP5520
     17H INCHES/)                                                          OUTP5530
2270 FORMAT(43X,13HAPPLIED LOADS)                                          OUTP5540
2280 FORMAT(53X,15HUNIFORM PRESSURE)                                       OUTP5550
2290 FORMAT(53X,15HSIMPLE SUPPORTS//)                                      OUTP5560
2300 FORMAT(53X,14HFIXED SUPPORTS//)                                       OUTP5570
2330 FORMAT(50X,F6.2,3X,F6.2,11X,F8.3,13X,F6.1)                            OUTP5630
2340 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//51X,             OUTP5640
     126HELASTIC DEFLECTION SUMMARY////23X,21HBEAM STATION (INCHES))       OUTP5650
2350 FORMAT(13X,9HTIME(MIN),3X,10(F5.2,5X)/)                               OUTP5660
2360 FORMAT(13X,F7.2,3X,10(F7.4,3X))                                       OUTP5670
2370 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//53X,             OUTP5680
     124HCREEP DEFLECTION SUMMARY////23X,21HBEAM STATION (INCHES))         OUTP5690
2380 FORMAT(13X,5HCYCLE,8X,10(F5.2,6X)/)                                   OUTP5700
2390 FORMAT(13X,I3,8X,10(F10.5,1X))                                        OUTP5710
2400 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//51X,             OUTP5720
     123HRESIDUAL STRESSES (PSI)//64X,6HCYCLE ,I3////25X,                  OUTP5730
     221HBEAM STATION (INCHES))                                           OUTP5740
2410 FORMAT (3X,6HHEIGHT,6X,10(F6.2,5X))                                   OUTP5750
2420 FORMAT (3X,F5.4,5X,10(F10.2,1X))                                      OUTP5760
2430 FORMAT(1H1,49X,33HCREEP PREDICTION COMPUTER PROGRAM//57X,             OUTP5770
     123HCREEP STRAINS (PERCENT)//64X,6HCYCLE ,I3////25X,                  OUTP5780
     221HBEAM STATION (INCHES))                                           OUTP5790
2440 FORMAT(3X,6HHEIGHT,6X,10(F6.2,5X))                                    OUTP5800
2450 FORMAT(3X,F6.4,5X,10(F10.7,1X))                                       OUTP5810
     END
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C-34